General Geology Report G 50

1965

Guide to the Horse Shoe Curve Section Between Altoona and Gallitzin, Central Pennsylvania

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COMMONWEALTH OF PENNSYLVANIA
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BULLETIN G 50

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PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG

1965

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GUIDE TO THE HORSE SHOE CURVE SECTION BETWEEN ALTOONA AND GALLITZIN, CENTRAL PENNSYLVANIA*

By

Frank M. Swartz**

INTRODUCTION

The cuts along the main line of the Pennsylvania Railroad in the vicinity of the Horse Shoe Curve west of Altoona, Blair County, Pennsylvania, expose one of the finest displays of later Paleozoic strata to be found along the course of the Allegheny Front. Beginning at Tunnel Hill on the eastern outskirts of Gallitzin, in the northeastern part of the Ebensburg quadrangle, the section extends eastwardly along the railroad right-of-way for a distance of more than 45,000 feet, and crosses in descending order approximately 7,000 feet in thickness of mostly shales and sandstones which increase progressively in geologic age from the base of the Pennsylvania Conemaugh Group close to the base of the Upper Devonian Chemung Shale. Opportunity is afforded on nearby roads to continue downward in the succession for another 1,800 feet to the Burket Black Shale at the Upper Devonian-Middle Devonian boundary.

From west to east along the course of the traverse, the strata lift to the surface with gradually steepening dips induced by rise toward the great geologic arch of Nittany Valley and Morrison Cove, and thus reflect the transition from the more northwesterly Allegheny Plateau province of nearly flat Carboniferous rocks, to the more southeasterly Appalachian Ridge and Valley province with its strongly folded and faulted structures. (Compare topographic map, Figure 7.)

* The Horse Shoe Curve section was measured in 1946 for presentation in a guide leaflet (Swartz, 1946) distributed in that year for a trip of the Twelfth Annual Field Conference of Pennsylvania Geologists. Description of the section as here given closely follows the account then used, although parts of accompanying discussions have been modified to give consideration to related, subsequent investigations by other workers.

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The stratigraphic sequence in the area of the Horse Shoe Curve has been described previously by Platt and Sanders (1877, 1881), and more especially by Butts (1905, 1918, 1945). Some faunal information has been furnished by Kindle (1906), as well as by Willard (1933, 1939) who also has offered comments bearing on correlation of some of the strata.

The account presented on the following pages has been prepared by the writer from traverses made in 1946 with the assistance of John C. Ferm, Steven S. Oriel and Allison R. Palmer. Landmarks, including mileage posts and signal towers, are recorded to aid identifications of horizons as well as locations. Distance footages of the traverse were made by measuring wheel, and presumably are subject to some corrections. The course of the traverse, and positions of outcrop stations and landmarks, are shown on the index map, Figure 6. Other sketches, incorporated in the text, illustrate some stratigraphic and faunal features.

A route that can be followed from the Penn Alto Hotel in Altoona to portals of tunnels of the Pennsylvania Railroad at Gallitzin, is first recorded, and the exposures studied along the right-of-way of the railroad are then described.

LOG OF ROUTE FROM PENN ALTO HOTEL IN ALTOONA, PENNSYLVANIA, TO TUNNELS OF PENNSYLVANIA RAILROAD AT GALLITZIN

Miles

0.0 Penn Alto Hotel, 12th Street and 13th Avenue, Altoona, Pennsylvania. Drive southwest on 13th Avenue. At 0.1 to 0.2 miles are exposures of Burket Black Shale, which also will be seen at Endress School at end of trip.

0.4 Turn right on 16th Street and then immediately bear left onto Washington Avenue, which continues into Route No. 36. Follow Route No. 36 to 7.8 miles.

Greenish gray shales and sandstones of the Upper Devonian are locally exposed along highway at 1.1, 1.3 and 1.4 miles.

2.6 Basal beds of the Catskill Formation are exposed at summit of a prominent foothill, from which there is a fine view of the main escarpment of the Allegheny Front, made by the Burgoon Sandstone Member of the Pocono Formation. The highway then descends into a broad valley.

Miles

4.0 Red and some green sandstones of the Catskill Red Beds are exposed as the highway begins ascent to Allegheny Front.

Greenish sandstones of lower part of Pocono Formation crop out at 4.2 to 4.25 miles; reddish sandstones at 4.4 miles; greenish sandstones and shales, partially concealed, at 4.4 to 4.6 miles.

Thick-bedded sandstones of the Burgoon Member are exposed at 4.8 to 5.4 miles, well up ascent of the escarpment of the Allegheny Front. In clear weather, there should be fine views backwards toward the east.

Some reddish mudrocks and sandstones of the Mauch Chunk Formation are exposed at 5.8 miles.

6.2 At top of mountain turn left, keeping on Route No. 36 toward Ashville. Buckhorn Rusty Coal Mine is to left at 6.5 miles. Sandstones are exposed at 7.3 miles, shales at 7.7 miles.

7.8 Turn left from Route No. 36, onto road to Coupon (1 mile) and Gallitzin (6 miles).

8.9 Coupon village. The road in this general area crosses Allegheny and Conemaugh beds of the moderately dissected surface of the Allegheny Plateau. At 10.15 and 10.5 miles there are fine views eastwards toward crests of the Allegheny Front made by the eastwardly rising sandstones of the Burgoon Member of the Pocono Formation.

11.1 Side road on left leads to Horse Shoe Curve. Continue straight. At 12 to 13 miles, the road follows a low ridge capped by the Ebensburg Sandstone Member of the Conemaugh Formation. As the surface then descends toward Gallitzin, there is a fine view to the left of the environs of the Valley of Sugar Run, where drainage flows to the Juniata River, whereas to the right or west is the headwater region of Clearfield Creek, which flows northeastward to the West Branch of the Susquehanna River. At Cresson, 2½ miles southwest of Gallitzin, is the divide separating drainage to the Susquehanna River and the Atlantic Coast from that flowing to the Conemaugh River and to the Gulf Coast.

13.4 A road here turns sharp left to Gallitzin; do not turn but continue straight on road beginning a return to Altoona via the valley of Sugar Run. Conemaugh beds are exposed at the intersection.

13.8 Leave cars and take a dirt road to the left, walking to eastern portal of the east-bound, southern tube of the Gallitzin Tunnels of the Pennsylvania Railroad. (Note: With two or more cars, a party wishing to examine the Horse Shoe Curve section can continue along the road leading southeast along Sugar Run Valley, passing Blair School at 14 miles, and leave one car at a small turnout on the right side of the road at 16 miles, opposite entrance of a dirt road 0.25 miles west of the lower bridge crossing Sugar Run. Returning to the Gallitzin Tunnels, the section can be examined from Stop No. 1 to Stop No. 9 in the vicinity of Milepost 244 at 18,220 feet traverse; a path then can be taken down the mountain slope to the 16-mile location, to retrieve the cars for the drive to the Horse Shoe Curve to resume study of the section at Stop No. 10.)

DESCRIPTION OF EXPOSURES ALONG RIGHT-OF-WAY OF PENNSYLVANIA RAILROAD

Positions of landmarks and of suggested stops along the right-of-way of the Pennsylvania Railroad from the Gallitzin Tunnels to the vicinity of Milepost 239, at 44,435 feet traverse and 3 miles east of the Horse Shoe Curve, are shown on the index map, Figure 6, drawn with a scale of 1 inch equals 1,600 feet.

Beds of the Pennsylvanian Allegheny and Pottsville Groups, and of the Mississippian Mauch Chunk, Loyalhanna and Pocono Formations are extensively exposed from Stop No. 1 at the portal of the southerly, eastbound tube of the Gallitzin Tunnels, to Stop No. 9 in the vicinity of Milepost 244 at 18,220 feet traverse. Transfer can then be made to Stop No. 10 at the Horse Shoe Curve at 28,900 feet traverse, where sandstones of the upper, Burgoon Sandstone Member of the Pocono Formation form high cliffs at the nose of Kittanning Point. Red beds of the Devonian Catskill Formation are extensively exposed in the vicinity of Stops Nos. 11 and 12, and fossiliferous shales and sandstones of the Chemung Formation are visited at Stops Nos. 13, 14, 15 and 16. From Stop No. 16, the route of the trip leaves the railroad right-of-way, and follows the Burgoon Run Road to Burket village as mapped on the Hollidaysburg topographic sheet, to visit parts of the Devonian Brallier, Harrell and Burket Formations.

Rocks exposed at the stops and inter-stop areas, continuing progressively downwards in the section, are described below.

STOP NO. 1

UPPER PART OF ALLEGHENY GROUP

Beds of the basal part of the Conemaugh Group and upper part of the Allegheny Group are exposed for a distance of 620 feet traverse eastward from the eastern portal of the southern, eastbound tube of the railroad tunnels at Gallitzin. The Upper Freeport coal, its top by definition the upper boundary of the Allegheny Group, is well shown as is the nonmarine Upper Freeport limestone.

For the strata exposed at Stop No. 1 and elsewhere, footage thicknesses are given for individual beds, and cumulative totals are carried downwards from the top of the Upper Freeport coal.

PENNSYLVANIAN SYSTEM Conemaugh Group	Feet Bed	 Total
Concealed on hill above tunnel.		
Thin-bedded, greenish-gray shales, exposed above and near eastern portal of tunnel.	40	
Exposed shales of basal part of Conemaugh Group	40	
Allegheny Group		
Upper Freeport coal.	6	6
Gray fireclay above, concealed below.	3	9
Thin-bedded, fine-grained silty sandstone, some shale.	1½	10½
Thin-bedded, greenish-gray shale.	6½	17
Upper Freeport limestone.—Thin- to medium-bedded, impure limestone, with some interbedded shale especially at 14 to 16 feet below top. In upper 8 feet, limestones are medium-bedded, and are weathered with ferruginous surfaces lighter in color than those of next lower beds. Marine fossils have not been observed in the Upper Freeport limestone either here or elsewhere in western Pennsylvania. The limestone thus is suggestive of the fresh water limestones reported locally by Wanless and Weller (1932) in the lower, continental hemicycle of Pennsylvania cylothems as described by them in Illinois. The strata associated with Pennsylvanian coal beds in western Pennsylvania generally occur in cycles suggestive of those in Illinois, although marine parts tend to be less well developed because of greater original distance from marine-water connections. Grouping the beds of a cycle from base of coal to base of coal, the individual, lower bed of coal or its rider commonly is overlain by brackish-water to marine shales, in part containing beds of marine limestone. Above this are fresh-water sandstones and shales, rarely, as in the Upper and Lower Freeport, with beds of fresh-water limestone. Underclay at the top of the fresh-water deposits is then overlain by the next bed of coal. Lateral, facies intergradations in coal-bearing deposits in western Pennsylvania have been recognized in recent years by Williams, Ferm and associates (1964a, 1964b), and it is suggested by Williams (1965) that the slump-filled channels that are prominent in inter-coal beds in parts of the Allegheny Group, represent the stages in emergence at which prominent underclays were formed by leaching in the inter-channel areas. On south side of tracks, base of Upper Freeport limestone is located at 408 feet traverse.	25	42
Thin-bedded shale, weathered greenish gray. Base is located near signal tower at 612 feet traverse.	12	54
Lower (?) Freeport coal, weathered, poorly exposed.	1	55

Thickness of beds of uppermost part of Allegheny Group, exposed at Stop No. 1	55

(First Signal Tower: traverse location 612 feet.)

AREA BETWEEN STOP NO. 1
AND STOP NO. 2

Concealed for long distance, to 5,220 feet traverse, the west-bound tracks joining the east-bound. There are old coke ovens south of the tracks from 1,700 to 2,300 feet traverse; the Bennington Mine south of Sugar Run is about opposite 4,500 feet traverse. Neighboring hills to the north and south rise to altitudes of 2,300 to 2,500 feet, and are capped by basal beds of the Conemaugh Group. Thickness about	250±	300±

(Second Signal Tower: traverse location 5200 feet.)

STOP NO. 2

LOWER PART OF ALLEGHENY GROUP AND MIDDLE AND UPPER PARTS OF POTTSVILLE GROUP

Basal beds of the Allegheny Formation or Group as mapped by Butts (1905, 1945) in the Ebensburg and Hollidaysburg quadrangles, together with upper, thick-bedded sandstones and associated shales of the Pottsville Group, are exposed at Stop No. 2 in railroad cuts at 5,220 to 6,430 feet traverse in the vicinity of former Bennington settlement.

Especially interesting features are (1) the fluviatile body of sandstone at 5,475 to 5,740 feet traverse which fills a broad channel cutting the 7 feet of shale next above the Mercer (?) coal; as at many places, there is little evidence that cutting of the channel was accompanied by appreciable erosion of the surface of presumably-matted peat from which the coal was derived; (2) the fine fossil specimens of lepidodendralians in the fresh-water, strongly cross-bedded Upper Connoquenessing (?) sandstone, that evidently at the time of sedimentation were logs brought in by presumed river transport; (3) the channel-fill thickening at base of the sandstone at the eastern end of the cut, that at first sight lends an appearance of flexuring to the junction with the subjacent shale.

The rock succession at Stop No. 2 is as follows.

Allegheny Group (continued) and Mercer (?) shale of Pottsville Group	Feet *Bed*	Feet *Total*
Thin-bedded, strongly cross-bedded sandstone and some shale.	10	310
Coal bed, identified by Butts (1905) as Clarion coal.	3	313
Thin-bedded shale with thin-bedded, irregularly bedded, interlayers of sandstone. Scour-and-fill structures occur near western end of cut.	10	323

Thin- to medium-bedded, very irregularly bedded sandstone filling a shallow, broad channel in the subjacent shale in area from 5,475 to 5,740 feet traverse, in the general fashion illustrated in Figure 1. Maximum thickness is 7 feet, with wedgeouts rapid at margins.	7-0	330
Thin-bedded shale, cut out where channel-fill sandstone is present.	0-7	330
Coal bed, classed as Brookville coal of Allegheny Formation by Butts (1905) on basis that it is lowest coal in shaly beds mapped as Allegheny Formation, but identified as presumed Mercer Coal by Williams (1960).* With the latter interpretation, this coal and associated shales and sandstones below base of Clarion coal and above Upper Connoquenessing sandstone are classed by Williams as Mercer beds of uppermost part of the Pottsville Formation or Group.	5	335
Gray underclay, 3 feet, above; concealed, below. Thickness somewhat variable.	5-10	340
Thickness at Stop No. 2 of exposed beds mapped as basal part of Allegheny Formation by Butts (1905, 1945), but including beds classed in Mercer portion of Pottsville by Williams (1960)	40-45	
Total estimated thickness below top of Allegheny Formation	340	

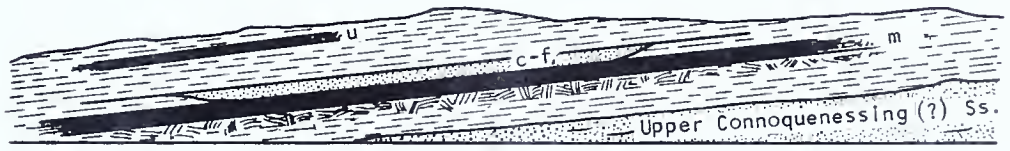


Figure 1. Channel-fill sandstone above Mercer (?) Coal, Stop No. 2 between 5,475 and 5,740 feet traverse. m: Mercer (?) Coal, u: upper coal, identified as Clarion Coal by Butts (1905), c-f: channel-fill sandstone.

* Following extended regional studies, E. G. Williams (1960) has concluded that the 5-foot coal at Stop No. 2 probably is Mercer coal of the Mercer Formation of the Pottsville Group, because of apparent equivalence to coal 2½ miles farther to the southwest along highway No. 22 at Blair Gap, which is underlain by the diaspore phase that he has found in the area to be distinctive where present of the Mercer underclay. The diaspore phase is believed by Williams to have developed from active leaching during Mercer time in areas of comparative topographic highs. Lesser leaching of the underclay elsewhere, as in the vicinity of Stop No. 2, is thought to have been associated with lower topographic levels along belts where subsidence had favored accumulation of Upper Connoquenessing sands that are wanting by non-deposition in areas where leaching of the underclay became more active. Columnar diagram No. 23 in Figure 3, Williams (1960, p. 1294), represents the Pottsville section at Stop No. 2, and columnar diagram No. 24 of the same figure is illustrative of the Pottsville along highway No. 22 at Blair Gap.

Pottsville Group

Upper Connoquenessing (?) sandstone.—Thick-bedded, strongly cross-bedded, medium-grained, somewhat micaceous sandstone, well cemented and resistant, becoming less massive toward top. Base forms a broad arch, not due to flexuring but because at eastern end of cut sandstone cuts deeply by scour-and-fill into upper part of subjacent shale, in the general fashion illustrated in Figure 2. Transection of

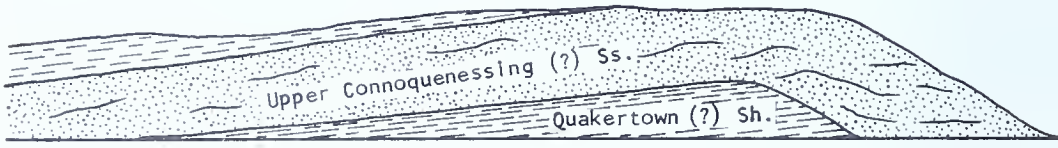


Figure 2. Cut-and-fill of base of Upper Connoquenessing (?) Sandstone, in area from 6,230 to 6,400 feet traverse.

stratification of the shale is well exhibited. Land plant fossils are common; fine specimens of lepidodendralians, evidently brought as logs into these generally fluviatile sediments, are located on the northerly side of the cut at 40, 55 and 65 feet and elsewhere east of the third signal tower at 5,922 feet traverse. (Please leave specimens for future visitors.) Dip 3° NW. Thickness generally is 15 to 22 feet, thickening at the channel-fill to more than 40 feet. The listing of this sandstone by Butts (1905, 1945) as Homewood Sandstone was followed by the writer in 1946 in his guide leaflet for the 12th Annual Field Conference of Pennsylvania Geologists. Williams (1960) has proposed its reclassification as Upper Connoquenessing sandstone as a corollary of his conclusion that the first overlying coal is Mercer coal. 15-22 352

(Third Signal Tower: traverse location 5,922 feet)

Quakertown (?) clay and shale.—Thin-bedded, irregularly bedded underclay and shale, above, and thin- to medium-bedded, fine-grained micaceous sandstone and interbedded shale, below. On northern side of cut, the strata reach their maximum exposed thickness of 18 feet at 6,230 feet traverse, then are truncated to and below track level at 6,350 feet by cut-and-fill of the overlying sandstone. Butts (1905, 1945) reported that small pockets of coal as much as 2 inches in thickness occur at the top of the underclay, enclosed partly in basalmost parts of the superjacent sandstone. He classed the underclay and interbedded shale and sandstone as Mercer shale, and reported discoveries of fossils of small plants which were considered by David White to be characteristic Mercer forms, although species were not listed. 18-0 380

Area Between Stop No. 2
and Stop No. 3

Concealed across small valley east of former Bennington settlement, to 7,115 feet traverse. 20± 400

STOP NO. 3

LOWER PART OF POTTSVILLE GROUP

The Lower Connoquenessing sandstone of the lower part of the Pottsville Group in terms of its development in the region of the Horse Shoe Curve, is finely exposed in bluffs at 7,115 to 7,890 feet traverse, with some beds of Quakertown (?) shale locally at summits of the cut at the western end. Land plant fossils are indicative of the nonmarine origin of the sediments, although they were brought in by transport rather than grown in place. Cross-bedding is extensively developed, having resulted from spreading of the sands by active currents.

The Pottsville Formation or Group receives its name from the town of Pottsville in the region of the Anthracite Fields of eastern Pennsylvania. Near Tamaqua, east of Pottsville, Ashburner (1883) reported thicknesses of 1,130 to 1,300 feet of Pottsville rocks that consist virtually throughout of conglomerates and sandstones, with a few thin streaks of coal, and with some subordinate red shale in the lower 400 feet. As compared to the deposits near Pottsville, the 100 to 120 feet of sandstones and shales of the Pottsville beds east of Gallitzin reflect a marked lessening in thickness of accumulation as well as reduction in general grain size with increasing distance from easterly source lands, perhaps with some overlap upon a subjacent surface of disconformity. Similar thicknesses of Pottsville rocks are reported in wells farther westwards toward Pittsburgh, where the deposits in part are represented by the so-called "Salt Sands".

The sandstones of the Pottsville Formation or Group in southwestern Pennsylvania are thought to represent only the upper part of the Pottsville accumulations that thicken to 2,000 and 3,000 feet and more in parts of southern West Virginia where they contain numerous beds of coal.

The Pottsville rocks below the Quakertown (?) shale at Stop No. 3 are as follows.

Pottsville Group (continued)	Feet	
	Bed	*Total*
Lower Connoquenessing sandstone.—Thick-bedded, strongly cross-bedded, somewhat micaceous sandstone, tending to break along the cross-bedding into slabs about 2 to 6 inches thick. Plant fossils occur in boulders at 7,300 feet traverse. Irregular, limonite-encrusted joint surfaces are prominent at 7,300 to 7,350 feet traverse. Bodies of shale, 1 to 2 feet thick, occur locally at 2 to 20 feet above base. The top of the sandstone remains above track level at western end of cut, but at top of bluff as much as 10 feet of basal beds of the Quakertown (?)		

shale occur locally on the irregular, upper surface of the Lower Connoquenessing sandstone. To 7,890 feet traverse.	50-60	450
Thickness of Pottsville Group about	100-120	

(Milepost 246: traverse location 7,675 feet.)

AREA BETWEEN STOP NO. 3 and STOP NO. 4

Concealed. Probably for most part consists of red mudrocks of the Mississippian Mauch Chunk Formation, but may at top include a small thickness of basal beds of the Lower Connoquenessing sandstone. To 9,305 feet traverse.	150±	600

(Signpost 4/3: traverse location 9,185 feet.)

STOP NO. 4

MAUCH CHUNK FORMATION OF MISSISSIPPIAN SYSTEM

Rocks of the Mauch Chunk Formation are exposed from 9,306 to 10,746 feet traverse, and include basal beds of an upper member consisting mostly of red mudrock, a lower-middle member of gray standstone that is Pocono-like in facies, and a lower, thin member of greenish-gray and red mudrock with interbedded siltstone and sandstone. The top of the gray standstone member is at about 10,000 feet traverse; conglomerates at the base of the gray sandstone member are exposed in the vicinity of Signal Tower No. 2454 at 10,782 feet traverse.

The Mauch Chunk Formation was named from Mauch Chunk on the Lehigh River in eastern Pennsylvania, where as reported by Lesley (1895) in the Final Report of the Second Geological Survey of Pennsylvania it is 2,168 feet thick and consists almost wholly of red shale or mudrock and red interbedded sandstone. Thicknesses are reported to reach 3,000 feet to the west of Mauch Chunk, and along the Susquehanna River north of Harrisburg the thickness may increase to be of the order of 5,000 feet. Thicknesses of about 1,000 feet are reported in the Broad Top Basin 25 miles southeast of Gallitzin.

West of the Gallitzin area, the Mauch Chunk beds extend below surface in western Pennsylvania as the thin "red rock" associated with the Big Lime or Greenbrier limestone. The Greenbrier limestone crops out in Pennsylvania along the flanks of Chestnut Ridge, evidently replacing parts of the Mauch Chunk Formation since there are tongues of red mudrock beneath it as well as above. The Greenbrier calcareous deposits thicken southwestward, reaching 800 feet or more in Greenbrier County in West Virginia and about 1,000 feet in parts of Mercer County in that State. The Greenbrier of the Chestnut Ridge region in Pennsylvania contains abundant fossils reported to furnish correlation with the Max-

ville Limestone of Ohio as well as with parts of the Greenbrier Limestone in West Virginia.

In the Horse Shoe Curve area, deposits of the limestone facies of the Greenbrier Formation have not been found, and no marine fossils have been observed in the Mauch Chunk deposits.

The succession at Stop No. 4 is as follows.

MISSISSIPIAN SYSTEM Mauch Chunk Formation	*Feet* *Bed*	 *Total*
Upper mudrock member		
Silty, in part calcareous mudrock, red 10 to 25 feet below top, with red and greenish-gray variegations in lower part.	42	642
Medium-grained, buff-weathered sandstone, at 9,684 feet traverse.	3-10	645
Silty mudrock, variegated red and green; bedding irregular, with layers tending to wedge in-and-out. To 10,006 feet traverse.	15-20	660
Thickness of exposed lower beds of upper mudrock member of Mauch Chunk Formation	60	
Thickness of upper mudrock member, in event full thickness of overlying interval should be included	210	
Middle sandstone member		
Thick-bedded, strongly cross-bedded, buff- and in part whitish-weathered, somewhat micaceous greenish-gray sandstones of Pocono-like aspect. Some local channel-cutting at top. Near middle are several 1-foot lenses of fine conglomerate, the matrix calcareous. Surfaces of sandstones at many places have 1- to 2-inch pits, formed in large part at least by weathering of flat to rounded fragments or nodules of limestone. This sandstone, as well as parts of the red mudrock members of the Mauch Chunk, plausibly interfingers southwestwards with the Greenbrier limestone. On the other hand, consideration is needed of the possibility that the member has extensions to the southeastwards that would be incorporated in the Pocono Formation as commonly understood in the Broad Top area, where the Loyalhanna Limestone is not recognized, although there appears to be less thickening there of the upper, Burgoon Sandstone Member of the Pocono than would be expected if this should be the actual relationship. To 10,464 feet traverse.	35	695
Concealed, the interval probably all represented in the sandstones measured in the next bluff. To 10,746 feet traverse.	—	—
(Signal Tower No. 2454: traverse location 10,782 feet.)		
Thick-bedded, cross-bedded sandstone, conglomeratic below, and having at its base a coarser, 0- to 2-foot conglomerate that occupies channels cut into top of next lower strata. In these basal conglomerates, pebbles are 1 to rarely 2 inches in diameter, and consist largely of milky		

quartz or more rarely of quartzites. Pebbles or possibly nodules of somewhat siliceous limestone are moderately common, and need testing for possible algal origins. Base reaches track level in vicinity of Signal Tower No. 2454.	30	725
Thickness of middle sandstone member of Mauch Chunk Formation about	65	
Lower mudrock and sandstone member		
Thin- to medium-bedded, greenish-gray siltstone, channel-cut at top.	3-6	730
Medium-bedded, cross-bedded sandstone, with solution pits formed by weathering of limestone fragments or nodules.	7	737
Reddish gray and some greenish-gray mudrock, and some greenish gray sandstone, with 8 feet of greenish-gray sandstone at middle. To 10,746 feet traverse.	18	755
Thickness of lower mudrock and sandstone member of Mauch Chunk Formation	30	
Thickness of Mauch Chunk Formation	305	

STOP NO. 5

LOYALHANNA LIMESTONE

The Mauch Chunk mudrocks and sandstone of the Horse Shoe Curve region are underlain by very strongly cross-bedded, calcareous sandstones and arenaceous limestones of the Loyalhanna Formation. The more calcareous portions are somewhat oolitic. Sand grains mostly consist of quartz, and commonly are rather angular. Butts believes that these strata can be traced southwestwards into beds of Fredonia-St. Genevieve age.

Loyalhanna rocks have been quarried extensively in central Pennsylvania for railroad ballast. The fresh rock is strengthened by its calcareous content, which also tends to favor some self-cementation of the ballast.

Exposures of the Loyalhanna are as follows:

Loyalhanna Limestone	*Feet* *Bed*	*Total*
Thick-bedded calcareous sandstone or arenaceous limestone, weathering with elevated, strongly cross-bedded, brownish-gray arenaceous bands, that enclose irregular, gray, more calcareous, somewhat oolitic bands or lenses, that weather to form deep ruts. To 11,352 feet.	10	765
Concealed, the interval represented by strata measured in the next bluffs. To 11,844 feet.	—	—

Thick-bedded, very strongly cross-bedded, calcareous sandstone and arenaceous limestone, the calcareous bands weathering into deep ruts. Base is 12 feet above track level at 11,844 feet traverse.	35	800
Thickness of Loyalhanna Limestone	45	

POCONO FORMATION
(STOPS NOS. 6 TO 8)

The beds in central Pennsylvania which have been mapped as Pocono Formation by Butts (1905, 1936, 1939, 1945), consist of gray sandstones and shales that lie between the Mississippian Loyalhanna Limestone or where this is wanting the Mauch Chunk Red Beds, above, and the Upper Devonian Catskill Red Beds, below. (See Figure 3.) They measure 955 feet in thickness at the Horse Shoe Curve. Sandstone of the upper third or somewhat more, 365 feet thick at Stop No. 6, are thick bedded and resistant with little shale and constitute the Burgoon Sandstone Member; they are the principal contributors holding up the escarpment of the Allegheny Front. Below the Burgoon is a weaker complex that for the present discussion is grouped as the "middle sandstone and shale member". These beds are 470 feet thick at Stop No. 7. Near the top they include some reddish layers thought to be representative of the red Patton shale, and other reddish layers occur subordinately in the lower part of the member. In the middle part, there are several interbodies of sandstone that are somewhat more prominent that those above and below. At the base of the Pocono are thick-bedded sandstones with little shale that are here treated as the "lower sandstone member", and that are 120 feet thick at Stop No. 8.

Cross-bedding is extensively developed in sandstones of all members of the Pocono Formation at the Horse Shoe Curve, and is suggestive of fluviatile modes of accumulation. Most of the sandstones are sharply separated from the subjacent shales, and further evidence of active scour is given by cut-and-fill in channels of which some are 5 and 10 to 15 feet and more in depth. The sandstones in part are somewhat micaceous, and in general do not appear to be composed of well-cleansed quartz sand. They mostly are gray to greenish gray in color, tending to weather to various tones of buff and tan.

The indications of fluviatile-lagoonal deposition that are afforded by the sedimentary features of the Pocono deposits at the Horse Shoe Curve are strongly enhanced by the abundance at many horizons of leaves and stems of land plants, and the limitation of invertebrates, so far as observed, to only a few, small and thin-shelled pelecypods and, at one horizon, a species of *Lingula*. A few plates of an ostracodermous fish also have been found.

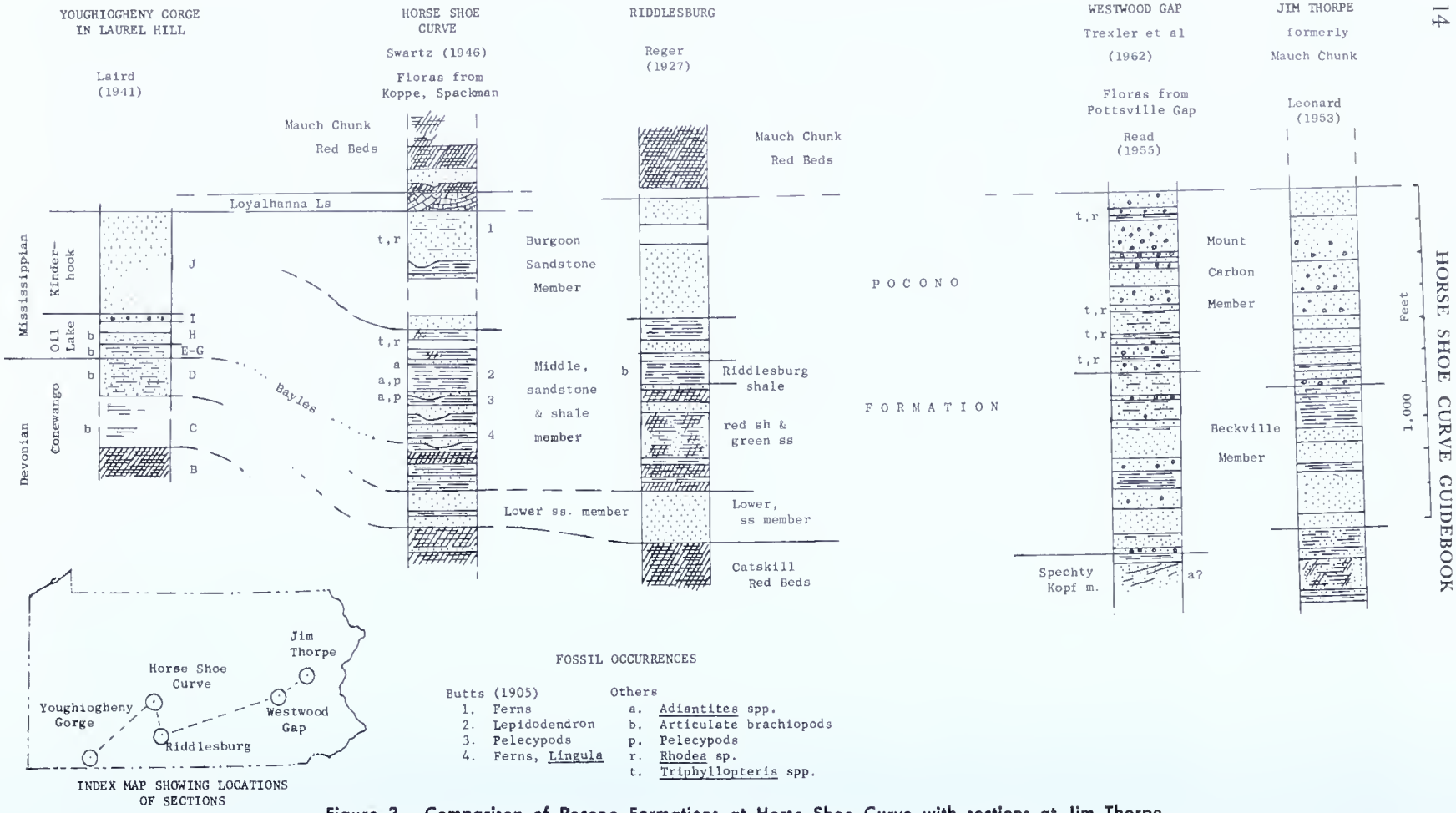


Figure 3. Comparison of Pocono Formations at Horse Shoe Curve with sections at Jim Thorpe, Westwood Gap, Riddlesburg, and Youghiogheny Gorge.

The fossil plants of the Pocono Formation provide information concerning the environment of sedimentation and also offer much value for correlation. In a columnar diagram in the folio for the Ebensburg quadrangle, in which details of the succession of sandstones and shales permit fairly confident integration with units described in the present account, Butts (1905) noted the occurrence of ferns about at horizon No. 1 as plotted here in Figure 3; of Lepidodendron at horizon No. 2; of fragments of a pelecypod at horizon No. 3; and of ferns and a *Lingula* at horizon No. 4. Plant species from the Curve subsequently were listed as follows by Butts (1936, 1939) on the basis of identifications by David White: *Rachopteris* sp., *Lepidodendron chemungense?* (Hall) Dawson, *L. corrugatum* Dawson, *L. corrugatum* var. *approximatum* White, *L. scobiniforme* Meek, *Sphenopteris* cf. *S. vespertina* White. The brachiopod from horizon No. 4 was identified as *Lingula gannensis* Herrick, and the pelecypod at a higher level was said to resemble *Mytilarca*. Butts concluded: "The Lepidodendrons, except possibly *L. chemungense?*, are Mississippian; so is the *Lingula*. The Pocono therefore is correlated with the Price sandstone of Virginia, which also contains *Lepidodendron scobiniforme* common, and an invertebrate fauna definitely correlating it with the Cuyahoga group of Ohio." In 1936, but not in 1939, Butts in addition cited "*Archaeopteris*, probably n. sp." as a member of the flora at the Curve, presumably in reference to specimens at the United States National Museum that Arnold (1939) later placed in *Archaeopteris latifolia* Arnold with the comment that "The *Archaeopteris* horizon at the curve has been included in the lower part of the Pocono, but it is definitely Devonian, though post-Chemung". Whereas Arnold appears to have proceeded from a generalization that *Archaeopteris* does not continue above the top of the Upper Devonian, Butts (1936) reported that *A. obtusa* Lesquereux occurs in the Lower Mississippian near Bingham, McKean County, Pennsylvania.

Positions within the Pocono Formation were not specified by Butts at places where he listed the species identified from the Horse Shoe Curve, and at least in terms of published information can be judged only from the notations accompanying his columnar diagram of 1905. It is likely that most if not all of the cited examples of Lepidodendron were obtained at horizon No. 2. The specimens of *Archaeopteris latifolia* Arnold at the National Museum were collected by M. R. Campbell in 1903 and presumably were known to Butts in 1905, and since Arnold states that they are considered to be from the lower part of the Pocono it appears plausible that they were found in the lower of the two occurrences of ferns listed by Butts, namely at horizon No. 4 about as plotted in Figure 3.

The fossil plants of the Pocono Formation in Pennsylvania and of the Price Sandstone in the Virginias subsequently have been reviewed by Read (1955, 1964) with recognition of a widespread, upper zone of *Triphyllopteris* spp., and of a lower zone of *Adiantites* spp. Read agrees with Jongmans' (1954) assessment that the Pocono assemblages are representative of a *Lepidodendropsis* flora of "worldwide" occurrence, and in commenting on the plants of the *Adiantites* zone stated that "Similar floras characterized by *Adiantites* and *Rhacopteris* are also known in the lower part of the Lower Carboniferous sequences of nonmarine facies in South America (Read, 1938, 1941a, 1942), Australia (David and Sussmilch, 1931), and Europe (Jongmans, 1939)".

With respect to specimens from the Pocono Formation at and near the Horse Shoe Curve, Read reported that *Adiantites spectabilis* Read, *Lagenospermum* sp., and *Girtya pennsylvanica* Read occur near the base of the Pocono at Bell's Gap 10 miles to the northeast, at 9 to 23 feet above the Pocono-Catskill boundary in unit No. 8 of his section description, and that there are abundant specimens of marine invertebrates in unit No. 5 at 27 to 30 feet, and some of a *lingula* in unit No. 4 at 30 to 36 feet. He added that at a "somewhat higher level" in the lower Pocono at the Curve itself there are found *Rhacopteris latifolia* (Arnold) Read, *Adiantites spectabilis* Read, *Rhodea* sp., *Alcicornopteris altoonensis* Read, and *Lepidodendropsis* sp. The specimen of *Rhacopteris latifolia* that had been illustrated by Arnold from collections made by Campbell in 1903, was refigured by Read, and for reasons previously considered may have been obtained at horizon No. 4 of Butts (1905). Since the other plants are coupled by Read with *R. latifolia* in his list of species from the lower part of the Pocono at the Curve, it is possible that they also came from the same collection and perhaps the same horizon, but the evidence is not clear.

Plants of the upper part of the Pocono at the Horse Shoe Curve were not reviewed by Read. As found at other localities, the species *Lepidodendron scobiniforme* Meek identified by White at the Curve presumably from Butt's horizon No. 2, was classed in *Lepidodendropsis* by Read, and *Lepidodendron corrugatum* Dawson was considered to be a possible synonym.

Further valuable information concerning the floras of the Pocono at the Horse Shoe Curve has been contributed recently by W. Spackman and by E. F. Koppe. Spackman (personal communication, 1956) has obtained specimens from the upper part of the middle sandstone and shale member at 425 feet below the top of the Pocono Formation, and also in the middle part at 560 to 570 feet, that agree with the forms classified by Read as *Adiantites spectabilis* Read and *A. ungeri* Read. Koppe

(personal communication, 1965) revisited the Curve in July, 1965, and observed *Triphyllopteris* sp., *Rhodea* sp., and *Girtya pennsylvanica* Read at horizons in the Burgoon Sandstone Member, and *Triphyllopteris* sp. and *Rhodea* sp. loose in the highest part of the middle sandstone and shale member. *Adiantites* sp. was found in the middle member at 460 to 480 feet below the top of the Pocono Formation, and at 520 to 540 feet Koppe collected *Adiantites spectabilis* Read, *A. ungeri* Read, and *Lepidodendropsis scobiniformis* (Meek) Read, together with small pelecypods. A lepidodendralian stem found at 590 feet does not belong in *Lepidodendropsis*. Several leaf fragments in plant "trash" at 607 to 637 feet below the top of the Pocono appear suggestive of the Upper Devonian genus *Archaeopteris* (Dawson) Read as restricted by removal of species such as *Rhacopteris latifolia* (Arnold) Read and *Archaeopteris bockschiana?* (Goeppert) Lesquereux = *Adiantites ungeri* Read, but Koppe states that better material will need to be found before identification of plants at this horizon can be considered to be satisfactory even on a generic basis.

The distributions of plants as well as of other fossils so far reported in the Pocono Formation at the Horse Shoe Curve, are summarized in Table I with indication of the source of each of the records. The plants reported by Koppe from the Burgoon Member, as well as those from the highest part of the middle sandstone and shale member, are representative of the widespread and distinctively Mississippian *Triphyllopteris* flora that was considered by David White (1934) to be characteristic of at least the easterly phases of the Pocono deposits, and that has been found by Read (1955, 1964) to mark a zone in the upper part of the formation. Below this, the *Adiantites* flora is well developed in at least the middle part of the middle sandstone and shale member. *Adiantites spectabilis* also may occur at the Curve at horizon No. 4 of Butts, although it is less clear than would be desirable that the specimens so identified by Read came from this position. The plants and invertebrates reported by Read (1955) from Bell's Gap, 10 miles northeast of the Curve, in beds considered to lie within a few feet of the Pocono-Catskill contact, occur in a sequence with more shale and siltstone than characterize the lower sandstone member of the Pocono at the Curve, and the stratigraphic position of the beds needs to be reinvestigated.

Among the invertebrate fossils at the Horse Shoe Curve, the pelecypods reported by Butts (1905) at horizon No. 3, and those found by the writer at perhaps the same level at 560 to 570 feet below the top of the Pocono beds, as well as those collected by Koppe somewhat higher at 520 to 540 feet, do not now appear to offer much promise for help in correlation. However, in their small size and thin shells, in the rarity if not absence

TABLE I

Fossils reported in Pocono Formation at Horse Shoe Curve section near Gallitzin, Pennsylvania, and near base of Pocono at Bell's Gap 10 miles to the northeast

Type of rock, and footage below top or above base of Pocono Formation	Fossils.— A: Arnold (1939). K: Koppe (1965). R: Read (1955). Sp: Spackman (1965). Sw: Swartz (1945). W: David White, in Butts (1936, 1939)
	Burgoon Sandstone Member
Shale, 110 feet below top of Pocono Formation	K: *Triphyllopteris* sp. *Rhodea* sp.
Shale, 150 to 180 feet below top of Pocono	K: *Girtya pennsylvanica* Read *Rhodea* sp.
	Middle sandstone and shale member
Shale chips, loose at 380 to 410 feet below top of Pocono	K: *Triphyllopteris* sp. *Rhodea* sp.
Shaly siltstone, 420 feet below top of Pocono	Sp: *Adiantites spectabilis* Read *A. ungeri* Read
Shale, 460 to 480 feet below top of Pocono	K: *Adiantites* sp.
Presumably at horizon No. 2 of Butts (1905), at about 500 feet below top of Pocono	W: *Lepidodendron scobiniforme* Meek = *Lepidodendropsis scobiniformis* (Meek) Read *Lepidodendron corrugatum* Dawson, perhaps = *Lepidodendropsis scobiniformis* (Meek) Read
Shale, 520 to 540 feet below top of Pocono Formation	K: *Adiantites spectabilis* Read *A. ungeri* Read *Lepidodendropsis scobiniformis* (Meek) Read Small, thin-shelled pelecypods, 5 to 6mm. in length at 525 feet, 2 to 2½ mm. in length at 535 feet
Shale, 560 to 570 feet below top of Pocono, at approximate position of horizon No. 3 of Butts (1905)	Sp: *Adiantites spectabilis* Read *A. ungeri* Read Sw: Small, thin-shelled pelecypod; rare plates of ostracodermous fish
Sandstone, 590 feet below top of Pocono Formation	K: Lepidodendralian stem, not *Lepidodendropsis*
Shale, 607 to 637 feet below top of Pocono Formation	K: Plant "trash". Koppe reports that several of leaf fragments are suggestive of *Archaeopteris* (Dawson) Read of Upper Devonian, but better material will be required to warrant identification of members of this flora

Horizon No. 4 of Butts (1905), at about 680 feet below top and 275 feet above base of Pocono Formation.	Butts: Ferns Brachiopod, identified as *Lingula gannensis* in Butts (1936, 1939)
Possibly at horizon No. 4 of Butts, but records will need clarification by future collecting	A, R: *Rhacopteris latifolia* (Arnold) Read R: *Adiantites spectabilis* Read *Rhodea* sp. *Alcicornopteris altoonensis* Read *Lepidodendropsis* sp.

Occurrences reported at Bell's Gap, 10 miles northeast of Horse Shoe Curve, at 9 to 36 feet above base of Pocono as described by Read (1955)

Unit 4, shale, 30 to 36 feet above base of Pocono	R: *Lingula* sp.
Unit 5, calcareous sandstone, 27 to 30 feet above base	R: "Abundant specimens of marine invertebrates"
Unit 8, shale and siltstone, 9 to 23 feet above base of Pocono Formation	R: *Adiantites spectabilis* Read *Lagenospermum* sp. *Girtya pennsylvanica* Read

of other shelly life, and in their association with abundant remains of land plants, they are of environmental interest as plausible indicators of comparatively fresh though perhaps from time to time somewhat brackish waters. Search for the pelecypods has not been extensive, and similar forms may occur at additional positions. The *Lingula* reported by Butts at horizon No. 4, and that by Read at Bell's Gap apparently close to the Pocono-Catskill contact, gives more definite evidence of brackish waters than is furnished by the pelecypods, but again there is no indication of truly marine conditions. Further information is needed about the membership as well as the stratigraphic level of the "abundant specimens of marine invertebrates" mentioned by Read (1955) at Bell's Gap, in beds reported to be 27 to 30 feet above the base of the Pocono.

A few plates of an ostracodermous fish occur with the pelecypods at 560 to 570 feet below the top of the Pocono Formation at the Horse Shoe Curve. According to Butts (1939, 1945), fragments of fish plates and small heads of calcareous algae are found sporadically in the thick-bedded sandstones of the basal part of the Pocono at various localities from Riddlesburg northwards at least to the Bellefonte quadrangle, and although they are not known at the Curve have been believed by him to give evidence of essential continuity of the Pocono-Catskill contact within this area.

Where traced elsewhere in Pennsylvania, the gray Pocono deposits that are so finely displayed at the Horse Shoe Curve undergo changes both in their own features and in relations to associated strata, and continue to offer problems that merit study and discussion. (Cf. Figure 3.) The formational name, Pocono, generally has been attributed to Lesley (1876), who with members of the Second Survey used it as a replacement

for the terms "Vespertine" of Rogers and "Formation No. X" of Second Survey reports. However, no type locality was designated, and distribution in the area of the Pocono Plateau and Pocono Mountain was so generalized on state geological maps even as late as 1931, that various uncertainties were introduced. Nevertheless, it is reasonably clear from the maps and reports of I. C. White (1881, 1882) and the concurring remarks by Lesley (prefatory letter, in White, 1882; also see Willard, 1936), that in the vicinity of the Poconos there was intention to have the name apply, in the fashion used for "Vespertine" by Rogers (1858), to the 1,000 feet and more of gray sandstones that rise in ridges first adjacent to valleys underlain by the Mauch Chunk Red Beds. Rogers, White and Lesley all refer to exposures of the formation along the Lehigh River opposite the town of Mauch Chunk, now known as Jim Thorpe, where according to Rogers there is a total thickness of 1300 feet, including a lower 500 feet of gray sandstone and some shale, overlain by gray sandstones with alternations of conglomerate. White (1882) estimated a thickness of 750 feet for the Pocono at this locality, with upper, conglomeratic sandstones, 150 feet, and basal, Mount Pleasant conglomerate, 50 feet. Winslow (1880) subsequently measured a thickness of 1253 feet, close to that given by Rogers, with conglomerates in and at the base of the upper 563 feet, but not well developed at the base of the formation.

The Pocono section at Mauch Chunk or Jim Thorpe that is here illustrated in Figure 3, is taken from a description by Leonard (1953) in an unpublished Master's Thesis at The Pennsylvania State University, which agrees generally with Winslow's account but is somewhat more detailed, and transfers to the subjacent Mount Pleasant beds of the Catskill Formation some gray silty shales and gray and variegated sandstones that were included in the basal part of the Pocono by the latter author. An upper member,* 599 feet thick as totaled, is composed of cycles tending to grade upward from conglomerate into sandstone and in some instances into a thin interval of shale, generally then with some truncation by scour below the base of the next higher beds. A lower member, 430 feet thick, consists of sandstone with few conglomerate layers, and with some shales, chiefly in the upper part. Leonard suggests that the Mauch Chunk section should be used as the selected type for the Pocono Formation, in view of its location neighboring the Pocono

* In Leonard's thesis, the upper and lower divisions of the Pocono at Mauch Chunk or Jim Thorpe are termed, respectively, the Bear Mountain Member and Silkmill Run Member. These members likewise were found in ridges along the rim of the Northern Anthracite Field, where they are overlain by a body of calcareous sandstone distinguished as the Abraham's Creek Member.

region and because of the attention it was accorded by Rogers, Lesley and I. C. White.

The subdivision of the Pocono beds recognized at Mauch Chunk or Jim Thorpe, appears to agree at least approximately with that used by Trexler, Wood and Arndt (1962) at a gap 29 miles to the southwest that is cut in Second Mountain by the West Branch of the Schuylkill River and that has been termed Westwood Gap by Read (1955). The upper, more conglomeratic portion, 560 feet thick at Westwood Gap, is named Mount Carbon Member, and the lower, less conglomeratic portion is named Beckville Member.* Below the Beckville Member are gray sandstones with some pebbly layers and with some beds of shale and siltstone, that are classed as Spechty Kopf Member and are placed in the uppermost part of the Catskill Formation because of a disconformity which separates them from the overlying Beckville sandstones.

There is little direct information concerning the fossil plants of the Pocono Formation at either Jim Thorpe or Westwood Gap. At Pottsville Gap in Second Mountain, 2½ miles east of Westwood Gap, however, characteristic species of the upper Pocono *Triphyllopteris* flora are reported by Read (1955) in beds that correspond more or less closely to the Mount Carbon Member of Trexler et al. *Triphyllopteris lescuriana* (Meek) Read is cited at 59 to 68 feet, 316 to 321 feet, and 544 to 565 feet below the top of the Pocono, with *Triphyllopteris* sp. at two intervening horizons, and *Rhodea vespertina* Read and *Lepidodendropsis scobiniformis* (Meek) Read are recorded at 59 to 68 and 544 to 565 feet below the top. The lowest of these horizons appears to lie close to the boundary between the Mount Carbon and Beckville Members. An *Adiantites* flora, including *Adiantites ungeri* Read, *Alcicornopteris anthracitica* Read and *Calathiops pottsvillensis* Read, is reported by Read at Westwood Gap at a position which he considered to lie at 390 to 392 feet above the base of the Pocono Formation.

The Pocono deposits of the area of Jim Thorpe and of Pottsville and Westwood Gap, are thus comparable in a degree to those in the vicinity of the Horse Shoe Curve, as least in that they include an upper, more coarsely textured portion that is characterized by the *Triphyllopteris* flora, above a lower, less coarsely textured portion in which the *Adiantites* flora is known at the Curve, at Pottsville and at Westwood Gap, and in which it perhaps will be found in the future in the more easterly region.

* Editors Note: Recent unpublished field data suggest that this correlation between Westwood Gap and Lehigh Gap may be doubtful. The "Bear Mountain" of Lehigh Gap appears more likely to be correlative with both the Beckville and Mt. Carbon Members at Westwood Gap, and the "Silkmill Run" appears to be correlative with the underlying Spechty Kopf.

Taking into account the paleobotanical data, together with the overall westwardly decrease in grain size that is prominent in both the Pocono and associated deposits and that has long been recognized in the region as a symptom of increasing distance from easterly source-lands, there is favorable evidence that the Burgoon Sandstone Member of the Pocono at the Horse Shoe Curve is the westward, more off-source and hence more finely textured extension of at least the bulk of the conglomeratic sandstones of the Mount Carbon Member of the Pocono in the area from Westwood Gap to Jim Thorpe, 115 to 145 miles to the northeast. It also is plausible that the middle and lower members of the Pocono at the Curve include continuations of the Beckville Member of the more easterly phases of the Pocono, but the relative position of the lower boundary remains uncertain, and the lower beds at the Curve may in part be representative of the Spechty Kopf Member that is treated by Trexler as a part of the Upper Devonian Catskill Formation, although it consists of gray sandstones and apparently contains *Adiantites* which is thought by Read to be indicative of early Mississippian age.

Returning from eastern to central Pennsylvania, the Pocono Formation as described by Reger (1927) at Riddlesburg on the flank of the Broad Top basin, 25 miles to the southeast (Fig. 7) and across the Nittany arch from the Horse Shoe Curve, consists as at the Curve of the upper, Burgoon Sandstone Member; of underlying sandstones and shales that can be placed in the middle sandstone and shale member; and at the base of thick-bedded sandstones attributable to the lower sandstone member. (See Figure 3.) The Loyalhanna Limestone, which lies above the Burgoon beds at the Curve, is not found at Riddlesburg. It possibly is wanting by disconformity, but neither is it unlikely that the strongly arenaceous Loyalhanna strata grade toward Riddlesburg into less calcareous sandstones that if present are incorporated in the Burgoon Member. The gray sandstones of the lower part of the Mauch Chunk at the Curve also are suggestive of Burgoon rocks, and if and where there is loss of identity of the subjacent, thin red layers as well as of the Loyalhanna Limestone, they may have easterly or southeasterly continuations that would fall within the Pocono as a lithologic body. Against this possibility at Riddlesburg, however, is lack of apparent thickening of the Burgoon as compared to its development at the Curve, and the marked expansion instead of the overlying Mauch Chunk Red Beds.

The rocks of the middle sandstone and shale member of the Pocono Formation are several hundred feet thicker at Riddlesburg than at the Horse Shoe Curve. At 130 to 205 feet below the top, Reger distinguished the Riddlesburg Shale, in which are found brachiopods, pelecypods and gastropods, together with an orthoceritid and one identified crinoid. As

studied by Girty (1928), the fauna is Early Mississippian in age and comparable to assemblages in Waverly deposits in northwestern Pennsylvania and Ohio. Although the invertebrates are comparatively diversified, Girty called attention to lack of observed productids and paucity of spiriferids, and these features in conjunction with the landward aspect of the deposits with which the Riddlesburg beds are interlayered suggests that the waters in this area did not achieve as full a marine salinity as did those of more open seas farther to the west. It would be of interest to speculate that the few species of pelecypods and lingulids of horizons Nos. 3 and 4 at the Horse Shoe Curve may be indicative of freshened lagoons or marshes in areas marginal to the Riddlesburg transgression, but as presently known their positions appear to be somewhat farther below the base of the Burgoon Member, at least in terms of thickness of sediment relative to the boundary as now drawn.

Red beds are distinctively more prominent in the lower part of the middle sandstone and shale member of the Pocono Formation at Riddlesburg than at the Horse Shoe Curve. They raise the question whether the deposits at this horizon may grade laterally toward the southeast into red bodies that at some places may be incorporated in the Catskill Formation.

Turning to the direction southwestward from the Horse Shoe Curve, as compared to the northeasterly location of Jim Thorpe and Westwood Gap and the southeasterly position of Riddlesburg, the gray Pocono-type deposits below the Loyalhanna Limestone and above red beds of the Catskill facies are reduced in thickness by almost one-third in the sixty-five miles of distance to Youghiogheny Gorge in Laurel Hill. (See Figure 3.) Upper sandstones, 310 feet thick according to Bayles (1949), have been placed in unit J by Laird (1941, 1942); they lack observed shelly fossils and have been supposed to include a thinned extension of the Burgoon Sandstone Member and of its subsurface continuations known under the name Big Injun Sand. Below unit J, unit I consists of 20 to 28 feet of conglomeratic sandstone, likewise without shelly fossils, correlated by Laird with the Berea or Corry Sandstone of the Mississippian of northwestern Pennsylvania. Next lower are fossiliferous units H, G, and E, with thin, intervening unit F at neighboring localities. The fauna of H, especially, contains species such as *Rhipidomella huntingdonensis* Girty, *Cypricardinia* aff. *C. consimilis* Hall, and *Palaeoneilo concentricus* Winchell, that likewise occur in the Riddlesburg shale at Riddlesburg. The faunas of H, G and E together are considered by Laird to be representative of assemblages found in northwestern Pennsylvania and Ohio in Cussewago beds of the Early Mississippian Oil Lake Series. The fossils of the next lower sandstones of unit D, on the other hand, contain species

that in northwestern Pennsylvania are distinctive of the Riceville deposits of the upper part of the Upper Devonian Conewango Series, and those of shale unit C are thought to be indicative of the Venango Stage of the Conewango. It thus is concluded that the Devono-Mississippian boundary falls about at the middle of the sequence of gray, Pocono-type sandstones and shales at Youghiogheny Gorge, rather than at either their upper or lower boundary.

The implications of Laird's results as they might apply to the section at the Horse Shoe Curve, were not immediately apparent. Although there was likelihood that lower parts of the gray Pocono sediments at the Curve may include equivalents of the gray, Late Devonian beds next above the red Catskill strata at Youghiogheny Gorge, the correlations at this level of detail appeared weak, and the possibility remained that there might be appreciable upward shift toward the Curve in chronologic position of the faciological red bed–gray bed boundary.

Data helpful for interpretation of relationships from Youghiogheny Gorge to the Horse Shoe Curve, subsequently were furnished by Bayles (1949). Using information from many deep wells across the western part of Pennsylvania, Bayles published stratigraphic charts indicative of widespread persistence of the subsurface Murrysville Sand in near-parallelism with the Pocono-Loyalhanna boundary at higher levels, as well as with the top of the lower-lying red beds of Catskill facies almost to the western limits of their occurrence. He concluded that by careful tracing there is strong evidence for correlation of the Murrysville Sand northwards and westwards with basal Mississippian Knapp-Cussewago beds in northwestern Pennsylvania and eastern Ohio; southwards into Laird's units E to H at the Youghiogheny Gorge in Laurel Hill; and eastwards with sandstones in the middle part of the middle sandstone and shale member of the Pocono at the Horse Shoe Curve, which by scaling from the charts appear to be those at 255 feet and higher above the Pocono-Catskill contact, as given in the writer's section in 1946. The base of the Murrysville Sand is thus considered by Bayles to correspond very nearly in position with the Devono-Mississippian boundary as it has come to be understood in the sediments of eastern Ohio and northwestern Pennsylvania on the basis of faunal correlations with strata of the Mississippi Valley. The horizon of the Devono-Mississippian boundary as projected by Bayles from Youghiogheny Gorge to the Horse Shoe Curve is plotted in Figure 3.

In terms of relationships at the Horse Shoe Curve, the correlation suggested by Bayles appears to be a helpful approximation, although it is evident in Figure 3 that the individual bodies of sandstone and shale that are illustrated within the middle member of the Pocono do not have

a closely similar sequence of counterparts at Riddlesburg and Youghiogheny Gorge with which direct lithostratigraphic correlation can be considered to be assured. The extensive occurrence of channel-cut-and-fill in the Pocono beds at the Curve, together with the abundance of remains of land plants and lack of fossils of marine organisms, suggest that the sand sediments may in that area have been spread largely in the advancing delta fronts and shifting channel areas of river distributaries in a region where there was associated deposition of lagoonal-estuarine and fluviatile muds and silts; such conditions would favor many wedge-outs in the smaller lithologic units. It is possible that the Murrysville Sand as understood by Bayles farther to the west in the increasingly marine phases of the accumulations, corresponds in a general way to the composite group of four sandstones illustrated in Figure 3 in the middle part of the middle Pocono member, rather than to any one of these bodies. Additional discoveries of fossil plants need to be sought in the lower beds of the Pocono at and near the Curve, as a possible source of greater clarity concerning details of the stratigraphic interrelationships, and for further lithostratigraphic studies the comparatively heavy-bedded sandstones of the lower member of the Pocono appear to offer promise for westward tracing in view of their persistence in surface sections from the Curve to Riddlesburg and elsewhere. It also seems more likely that correlatives of the lower sandstone member at the Curve will be found at Youghiogheny Gorge in Laird's sandstone unit D rather than in his shale unit C.

The questions that arise concerning details of correlation of the sandstones and shales of the Pocono in its broad sense at the Horse Shoe Curve have effects upon, but nevertheless are somewhat divergent from, the problems of arrangement of the deposits in stratigraphic units. The Pocono Formation as heretofore understood at the Curve constitutes a recognizable and mappable body of rock, distinct from the red Catskill beds, below, and the Loyalhanna Limestone and Mauch Chunk Red Beds, above. The upper, Burgoon Sandstone Member also is satisfactory as a rock unit in both of these respects, and on several maps has been shown by Butts separately from the sub-Burgoon portion; thus the combined middle and lower Pocono members as well as the Burgoon sandstones already have been found usable for mapping purposes and each could well serve as a formation. The thick-bedded sandstones of the lower Pocono member at the Curve could perhaps be distinguished as a mapping unit, although they tend to be poorly exhibited on the mountain slopes.

Separation of the Pocono-type beds at the Horse Shoe Curve into two formations bounded at or near the position of the base of the Murrysville

Sand as projected by Bayles, does not at present appear promising for use along the wooded slopes of the Allegheny Front and of the Pocono-crested ridges margining the Broad Top basin, although the possibility should receive further consideration especially if the presumed Late Devonian age of the lower beds is supported by future paleobotanical studies and other information. At Conemaugh Gap in Laurel Hill, 25 miles to the west of the Curve, Fettke and Bayles (1945) and Bayles (1949) have referred somewhat-fossiliferous gray sandstones and shales below the projected base of the Murrysville Sand to the Oswayo Formation, and have restricted the Pocono Formation to the overlying gray beds upwards to the base of the Loyalhanna Limestone. The name, Oswayo, was originally used by Glenn (1903) for Late Devonian olive-green and rusty-colored shales that in Cattaraugus County, southwestern New York, lie above the pink to red Cattaraugus Formation and below Knapp conglomerates. There are some thin interlayers of sandstone. Brachiopods and other shelly fossils are fairly common. The term was carried southeastwards by Fuller (1903a, b) into Potter County, north-central Pennsylvania, where it was applied to 1,000 feet of gray sandstones and shales above the Cattaraugus Formation and below Mauch Chunk shale, which are more arenaceous than the type Oswayo beds and are suggestive of the Pocono Formation as it has been understood at the Horse Shoe Curve although stratigraphic interrelationships are in need of further investigation. The lower portion of the gray sandstones and shales that have been included in the Pocono at the Curve plausibly are in part of the age of the Oswayo shales of southwestern New York much as was suggested by Bayles, but position of the upper limit is not well established and, in view of the differences in lithologic aspect and faunal facies, reference to the Oswayo Formation has not appeared desirable in the present discussion.

The Pocono sediments of the Horse Shoe Curve section, using the formational term in its broad sense, will be examined at three more or less distinct stops, at which features seen at the first, No. 6, are as follows.

STOP NO. 6

BURGOON SANDSTONE MEMBER

The Burgoon Sandstone Member of the Pocono Formation, exposed at Stop No. 6 at 11,845 to 14,540 feet of the Horse Shoe Curve traverse, exhibits the following features.

Pocono Formation *Burgoon Sandstone Member*	Feet *Bed*	 *Total*
Thick-bedded, markedly cross-bedded, in part micaceous, buff- to whitish- and greenish-weathered sandstone. There is some irregularly interbedded greenish-gray shale at 15 to 25 feet and 40 to 50 feet below top. Shale chips occur at a few horizons, as at 12,275 feet traverse. Butts (1905) reported fossil ferns in these strata, about at horizon No. 1 as shown in Figure 3. Representatives of the upper Pocono *Triphyllopteris* flora, found by Koppe (1965) at milepost 245 in beds 110 feet below top of the Pocono Formation, include *Triphyllopteris* sp., *Rhodea vespertina* Read. To 13,272 feet traverse.	150	950
(Milepost 245: traverse location 12,906 feet.)		
Thin-bedded shale, weathering yellowish gray to greenish gray, and some interbedded, somewhat lenticular, ½- to 1-foot interlayers of fine-grained sandstone. At 13,272 feet traverse, the overlying sandstone cuts sharply into a channel in this body of shale. Koppe (1965) reports: *Rhodea* sp., *Girtya Pennsylvanica* Read. To 13,398 feet traverse.	30	980
Thick-bedded, cross-bedded sandstone. To 13,476 feet traverse.	10	990
Concealed. To 14,166 feet traverse.	120	1110
Medium-bedded, rather fine-grained greenish-gray to buff-colored sandstone. At 14,166 feet, some shale occurs in bank above these sandstones. To 14,540 feet traverse.	55	1165
Thickness of Burgoon Sandstone Member of Pocono Formation	365	

STOP NO. 7

MIDDLE SANDSTONE AND SHALE MEMBER OF POCONO FORMATION

The Burgoon Sandstone Member is underlain in the Horse Shoe Curve section by 470 feet of interbedded sandstones and shales, which form a distinct middle member of the Pocono Formation as it has been mapped in the region. The deposits occur generally in cycles in the following manner.

~ Intercycle, scour and channel-cut features ~

Upper

Thin-bedded, comparatively regularly bedded, somewhat silty shales and some mudrocks, plausibly deposited in fresh-water to somewhat brackish lagoons and embayments. Plant fossils common. At one horizon, there are numerous small fern-like plants, so distributed as to suggest burial in place where engulfed in a flood of sediment. Small, thin-shelled pelecypods have been found in parts of two of the bodies of shale, and

Hemicycle the *Lingula* reported by Butts (1905) presumably came from one of the shales at a lower level. A few fish plates have been obtained at one horizon.

Lower Strongly cross-bedded, generally micaceous sandstones. Some plant fossils. Plausibly fresh-water fluviatile to perhaps in part lagoonal deposits. There is one body of red sandstone at 80 to 100 feet above base of member. The sandstone bodies in general tend to be gradational upwards into *Hemicycle* next overlying beds of shale, whereas at the base they commonly are sharply defined and locally fill channel-cuts in the subjacent shale.

~ Intercycle, scour and channel-cut features ~

Somewhat similar cycles continue upwards into the Burgoon Member, but the sand deposits become much thicker both in terms of individual bodies and in proportion to the shales, and red-colored beds are wanting.

The sand bodies may have been deposited in large part by shifting distributary streams, recurrently outbuilding at times and places where sedimentation matched or exceeded subsidence, whereas at other times and places clays and silts accumulated in lagoons and embayments which spread onto the slowly subsiding surface of deposition. Conditions of exposures in the region are not favorable for observation of the continuity and lateral extent of the bodies of sandstone and of shale.

The rocks of the middle, sandstone and shale member of the Pocono Formation at Stop No. 7 are described below. In terms of the concept of cycles outlined above, each body of shale should be combined in turn with the next subjacent body of sandstone.

Pocono Formation *Middle sandstone and shale member*	*Feet* *Bed*	 *Total*
Medium-bedded, greenish-gray siltstone and silty shale, reddish 4 to 5 feet above base. Some plant fossils. To 14,615 feet traverse.	15	1180
Concealed. To 14,840 feet traverse. In loose chips of shale obtained in this interval, Koppe (1965) reports *Tripyhllopteris* sp., *Rhodea* sp.	30	1210
(Watchman's house: traverse location 14,780 feet.)		
Thin-bedded, silty, somewhat micaceous, greenish-weathered shale, with some reddish variegations in lower half that give suggestion of the horizon of the Patton Shale. Some plant fossils. In upper part, Spackman (1965) reports examples of the plants referred by Read to *Adiantites spectabilis, A. ungeri;* these represent the highest observed occurrence of the *Adiantites* flora. To 15,095 feet traverse.	35	1245
Medium- to thick-bedded, strongly cross-bedded, buff- to greenish-colored sandstone. To 15,205 feet traverse.	15	1260
Thin-bedded, gray to greenish-gray shale, with 4 feet of greenish-gray, fine-grained silty sandstone at 60 to 64 feet below top. In upper third, shales generally are dark-gray and thin-bedded; below, they are more greenish and micaceous. Topmost 6 inches made of clay, sug-		

gestive of a regolith but perhaps more affected by Cenozoic groundwater circulation. Fossil plants common near base, rarer above. The lepidodendralians, presumably including *Lepidodendropsis scobiniformis,* reported by Butts (1905) apparently came from near the middle of these beds, at horizon No. 2 as plotted in Figure 3. In upper 20 feet, Koppe (1965) reports *Adiantites* sp. (r); in the lower 20 feet he found *Adiantites spectabilis* (a), *A. ungeri* (c), *Lepidodendropsis scobiniformis* (r). Small, thin-shelled pelecypods, 5 to 6 mm. in length, occur at about 15 feet above base, with smaller, more coarsely lamellose specimens, 2 to 2½ mm. in length, at about 5 feet above base. To 15,636 feet traverse.	80	1340
Medium- to thick-bedded, medium-grained, buff- to greenish-colored sandstone. To 15,700 feet traverse.	15-30	1360
(Signal Tower No. 2444: traverse location 15,700 feet.)		
Thin-bedded, greenish-weathered shale, truncated by channel-cut-and-fill at base of superjacent sandstone, so that shale thins from 15 feet in thickness near the signal tower to zero thickness in a distance of about 150 feet along the bedding. In upper 5 feet: plant fossils (c); small, thin-shelled pelecypod (c); fish scales (r). This appears to be the position, shown as horizon No. 3 in Figure 3, at which Butts (1905) reported pelecypods later considered to resemble *Mytilarca.* Spackman (1965) states that the plants include examples of the forms placed under the names *Adiantites spectabilis* and *A. ungeri* by Read (1955). Base of the shale is at track level at 15,755 feet traverse.	15-0	1375
Medium- to thick-bedded, strongly cross-bedded sandstone, with some interbedded greenish-gray shale at 21 to 24 feet below top. Koppe (1965) reports a lepidodendralian stem, which is not representative of *Lepidodendropsis.* To 15,895 feet traverse.	32	1407
Thin-bedded, greenish-gray shale, with a few thin interlayers of very fine-grained sandstone. Some plant fossils. In plant "trash" obtained from these beds, Koppe (1965) states that some of the leaf fragments are suggestive of *Archaeopteris,* although better material will need to be obtained before even generic determinations can be considered to be satisfactory, Dip 11° NW. To 16,045 feet traverse.	30	1437
Thin-bedded, silty shale, with 6 inches of yellowish clay at top. Small pelecypod (r). This appears to be the position, indicated as horizon No. 4 in Figure 3, at which Butts (1905) reported ferns, and a brachiopod later cited as *Lingula gannensis.* The ferns mentioned by Butts may have been the specimens collected by M. R. Campbell in 1903, from which Arnold obtained specimens of *Rachopteris latifolia* (Arnold, 1939) Read (1955), and with more uncertainty may have provided the material from which Read (1955) listed *Adiantites spectabilis, Rhodea* sp., *Alcicornopteris* Read, and *Lepidodendropsis* sp. New discoveries are needed to establish the membership of the flora at this and lower levels in the Pocono, as one of the factors that will help to provide more detailed correlations and interpretation of age relationships. To 16,320 feet traverse.	10	1484

Medium-bedded sandstone with well-marked channel cutting in lower part. Base is 700 feet below top and 255 feet above the Pocono-Catskill contact as here employed. These beds, in conjunction perhaps with the two or three next higher sandstones, constitute the general level to which Bayles (1949) has projected the Murrysville Sand and base of the Mississippian System. To 16,415 feet traverse.	16	1500
Thin-bedded, greenish-gray shale, with several interlayers of greenish gray sandstone, and with 2 feet of red mudrock at 5 to 7 feet below top. To 16,520 feet traverse.	22	1522
Red silty mudrock, with several thin interlayers of greenish-gray and some red sandstone.	15	1537
(Watchman's house: traverse location 16,555 feet. Note profile of high escarpment made by Burgoon Sandstone Member, to southwest across valley of Sugar Run. There also are fine views to the east and southeast toward Lock, Short and Dunning Mountains with their prominent talus slopes of white boulders derived from the Early Silurian Tuscarora Quartzite.)		
Thin- to medium-bedded red sandstone and some interbedded red mudrock. These and adjacent beds appear to represent tongues from red beds that are thicker in the lower half of the middle sandstone and shale member of the Pocono in the section at Riddlesburg. To 16,640 traverse.	18	1555
Thin-bedded greenish-gray and some reddish mudrock, with a few thin interlayers of sandstone. To 16,795 feet traverse.	37	1592
Medium-bedded, greenish-gray sandstone. To 16,910 feet traverse.	21	1613
Thin-bedded, greenish-gray shale, reddish at 11 to 16 feet below top. To 17,320 feet traverse.	22	1635
Thickness of middle sandstone and shale member of Pocono Formation	470	

STOP NO. 8

LOWER SANDSTONE MEMBER OF POCONO FORMATION

The thick-bedded sandstones that have been regarded by Butts as marking the base of the Pocono Formation in its occurrences along the Allegheny Front in central Pennsylvania, and that are here termed the lower sandstone member, are finely exposed at Stop No. 8, in the interval from 17,320 to 17,850 feet traverse.

The strata are as follows.

Pocono Formation *Lower sandstone member*	*Feet* *Bed*	 *Total*
Medium- to thick-bedded, strongly cross-bedded, greenish-gray to buff-colored sandstone, tending to break into 2- to 12-inch slabs. To 17,650 feet traverse. These sandstones form the lower part of an apparent cycle that continues upward into the 22 feet of greenish-gray shale and mudrock in the basal part of the middle sandstone and shale member.	70	1705
Dark red shale or mudrock, greenish-gray and lumpy and perhaps regolithic at top. To 17,675 feet traverse.	7	1712
Medium- to thick-bedded, strongly cross-bedded, greenish-gray to buff-weathered sandstone. To 17,850 feet traverse.	43	1755
Thickness of lower sandstone member of Pocono Formation	120	

STOP NO. 9

UPPER DEVONIAN CATSKILL RED BEDS

The uppermost 80 feet of the Upper Devonian Catskill Red Beds are exposed as follows at 17,850 to 18,882 feet traverse, where the railroad tracks turn to the northeast.

Devonian System Catskill Red Beds	*Feet* *Bed*	 *Total*
Thin-bedded, red silty mudrock, with a stronger rib 25 to 31 feet below top. At top are 2 feet of greenish clayey shale, possibly regolithic. To 18,005 feet traverse.	39	1794
Thin-bedded, greenish-gray silty shale. To 18,035 feet traverse.	9	1803
Medium- to thick-bedded, greenish-gray, fine-grained sandstone. To 18,000 feet traverse.	17	1820
Thin-bedded, greenish-gray and some reddish shale and mudrock. To 18,180 feet traverse.	15	1835
Thickness of uppermost beds of Catskill Formation exposed at Stop No. 9	80	

(Milepost 244: traverse location 18,220 feet.)

TRANSFER TO STOP NO. 10 AT HORSE SHOE CURVE

Beyond Milepost 244, the tracks extend northeastward and run lengthwise the strike for a distance of more than a mile without exposures.

Eventually, they curve northwestward, and from 24,590 to 28,110 feet traverse recross the upper part of the Catskill Formation and lower part of the Pocono beds, before reaching the watchman's house at the Horse Shoe Curve in its stricter sense at 28,930 feet traverse. Instead of walking from Milepost 244 to the Curve, it is possible in the event transportation has been arranged to take a path down the mountainside as shown on Figure 6, to the turnout at 16 roadlog miles on the highway in the valley of Sugar Run, and thence to drive to the Curve for renewed examination of the rock succession.

Driving southeastward along Sugar Run Road from the turnout at 16 miles of the road distances, Sugar Run is crossed at 16.25 miles. There is red Catskill soil and some Catskill exposures at places from 16.3 to 17.2 miles, and greenish-gray shales and sandstones of the Chemung Formation are loose in cuts at 17.4 to 17.7 miles and at 18.3 miles. The road curves sharply to the left at 18.55 miles near a red-brick school house and crosses Sugar Run at 18.6 miles. After crossing this bridge bear left. At 19.55 miles turn left and do not cross bridge over Burgoon Run. Cross run at 20.1 miles and turn left on Burgoon Run Road at dead end at 20.3 miles. There is red Catskill soil at 21.55 miles, with dams of reservoirs at 21.6, 22.55 and 23.2 miles. Parking space at the Curve is at 23.5 miles, and steps east of a small store lead to the watchman's house at the curve.

STOP NO. 10

TYPE LOCALITY, BURGOON SANDSTONE MEMBER OF POCONO FORMATION

At the sharp bend at the Horse Shoe Curve, the thick, resistant ledges of the Burgoon Sandstone Member of the Pocono Formation form high cliffs at the nose of Kittanning Point, above the tracks, and some of the lower beds are exposed along the tracks to the south of the watchman's house.

There are fine views at the Curve of the steep, Burgoon-made escarpment of the Allegheny Front, of the neighboring foothills, and of the three reservoirs that serve the City of Altoona, and that nestle in the valley of Burgoon Run.

The watchman's house at the Curve is located at 28,930 feet traverse as measured along the railroad tracks from the tunnels at Gallitzin. The traverse can here be resumed, following the railroad tracks toward Altoona, and continuing downward in the rock succession as follows.

	Feet	
	Bed	*Total*
MISSISSIPPIAN SYSTEM		
Basal part of Burgoon Sandstone Member, and middle and lower members of Pocono Formation		
Thick-bedded, greenish-gray to buff-colored sandstones of Burgoon Member of Pocono Formation, exposed above tracks in cliffs of Kittanning Point, and in part along tracks south of watchman's house in area from 28,690 to 28,930 feet traverse. No attempt was made to measure the Burgoon sandstones of the cliffs, but the member is 365 feet thick where previously described from the exposures at 11,845 to 14,540 feet of the traverse. The base of the beds exposed near the watchman's house apparently does not quite represent the position of the base of the Burgoon Member.		
Concealed at level of tracks, from vicinity of watchman's house at 28,930 feet traverse, to 29,866 feet traverse. Thickness poorly indicated. Beds probably include some of highest portion of the middle sandstone and shale member	100±	
Thin-bedded, greenish-gray shale, with several 10- to 20-foot interbodies of medium- to thick-bedded, greenish-gray sandstone. The interbedded shales and sandstones, and the reddish color of the next subjacent sandstone and shale are indicative of horizons within the middle sandstone and shale member of the Pocono Formation, with the top of the red layers approximately at 1200 feet as measured, stratigraphically below the top of the Upper Freeport coal. To 30,240 traverse.	55	1200
(Signal Tower: traverse location 30,240 feet.)		
Medium-bedded, red sandstone and interbedded red shale or mudrock. To 30,352 feet traverse.	20	1220
Concealed. To 32,326 feet traverse.	310	1530
(Watering Spouts: traverse location 30,556 feet.)		
Red sandstone, strongly cross-bedded, thick-bedded where fresh but breaking down after weathering into slabs 1 to 3 inches thick. On the basis of apparent thickness position below Burgoon Member, and thickness as sandstones without interbedded mudrock, these beds appear to belong in lower part of middle member of the Pocono Formation, but additional studies in the vicinity would be desirable for confirmation of relationships. To 32,458 feet traverse.	20	1550
Concealed, to Milepost 241 at 33,845 feet traverse. Judging from thicknesses measured in the vicinity of Stops Nos. 7 to 9, the Pocono-Catskill contact should occur perhaps somewhat west of Milepost 241, and is again recorded as at 1,755 feet stratigraphically below top of Upper Freeport coal. Further evidence concerning position of boundary would be desirable.	205	1755
Estimated thickness of interval of Pocono beds from watchman's house at Curve to base of Pocono as placed in vicinity of Milepost 241	655	

(Milepost 241: traverse location 33,845 feet.)

DEVONIAN SYSTEM
Catskill Red Beds

Concealed, with some red mudrock at 34,110 feet. To 34,146 feet. Portion of interval estimated to belong in Catskill Formation.	125	1880

STOP NO. 11

CATSKILL RED BEDS OF DEVONIAN SYSTEM

For the mile distance from 34,146 feet to 39,495 feet of the traverse, there are extensive exposures of the red shaly mudrocks and red sandstones that constitute the Catskill Red Beds of the Horse Shoe Curve region.

The red Catskill beds are 1675 feet thick at the Horse Shoe Curve section, on the basis of calculations using traverse distances and observed values of strike and dip. This figure may need some adjustment, since it is about 300 feet less than has been obtained in deep wells 10 miles and more to the west (see Bayles, 1949), in contrast to the expected tendency toward eastward thickening. The Catskill strata consist predominantly of red, shaly to silty mudrocks that break to hackly fragments. Interbeds of red sandstone occur at numerous horizons, but total less than half of the thickness of the mudrocks. Green shales and sandstones are subordinate. Comparative abundances of rocks of the several types are suggested by the following approximations.

Rock type	*Total thickness in feet*	*Percentages in terms of exposed beds*
Red mudrock	570	60
Red sandstone	265	27.9
Green shale	70	7.4
Green sandstone	45	4.7
Total, exposed beds	950	100
Concealed	725	
Total thickness	1675	

At many places, the sandstone beds are channel-cut into subjacent mudrock. Dimensions of the cuts are small as compared to those of the channels in the Pocono Formation with their common depths of 5, 10 and 15 feet. Cross-bedding is extensively developed in most of the beds of sandstone.

Fossils are sparse in the Catskill beds in the vicinity of the Curve. A few plates of ostracodermous fish have been discovered. Brachiopods occur in one 25-foot body of greenish-gray shale at 250 to 275 feet above base of the formation, but this occurrence is representative of a marine tongue that penetrates the Catskill mass from a westerly direction, and is foreign to the normal Catskill facies. Some fossils of land plants, including *Archaeopteris* as understood by Read (1955), have been reported in red Catskill rocks in the Broad Top basin to the south in the general vicinity of Riddlesburg, so that similar discoveries may be made in the future at the Curve as well.

From the investigations of many workers, including Clarke (1904), H. S. Williams (1909) and Chadwick (1933, 1935, 1936) in New York, C. K. Swartz (1913a, b,d) in Maryland, and Caster (1934) and Willard (1933, 1939) in Pennsylvania, it is evident today that the red Catskill accumulations were deposited in the fluviatile-lagoonal region of a delta coast that lay along the westerly margin of the eroding old-lands of Appalachia, and that they intergrade and interfinger toward the west into nonred, fossiliferous marine deposits which in turn exhibit effects of progressive change at the time of sedimentation from a shallower belt where bottom waters were higher in energy and well aerated, to more offshore positions where bottom conditions were quieter and oxygen less abundant and even deficient. (Cf. Figure 4.) With growing scope and clarity, the studies thus have enlarged upon stratigraphical and depositional interrelationships that in part were outlined by Clarke in 1904, when he recognized within the Upper Devonian of New York the indications of an easterly, freshened Oneonta embayment occupied in some degree by fishes and specialized arthropods, margined on the west by an Ithaca province of shallow marine waters inhabited by abundant brachiopods and other shelly organisms, and then by divisions of the more offshore Genessee province where brachiopods were few and faunas tended to consist instead of small pelecypods and some goniatites. Since subsidence of the surface of deposition did not keep full pace with accumulation, the belts of sedimentary and biologic facies shifted progressively toward the west, and the base of the red strata becomes younger in that direction, rising from horizons in the Middle Devonian in eastern New York, until in southwestern New York and northwestern Pennsylvania the red- and pink-colored layers do not occur below levels high in upper parts of the Upper Devonian, and eventually disappear entirely. The Upper Devonian succession at the Horse Shoe Curve is on the whole comparable to that in the Ithaca-Chemung area of New York (see Figure 4), and includes brachiopod-rich Chemung beds that lie as judged by membership of the fossil faunas at the general level of the similar

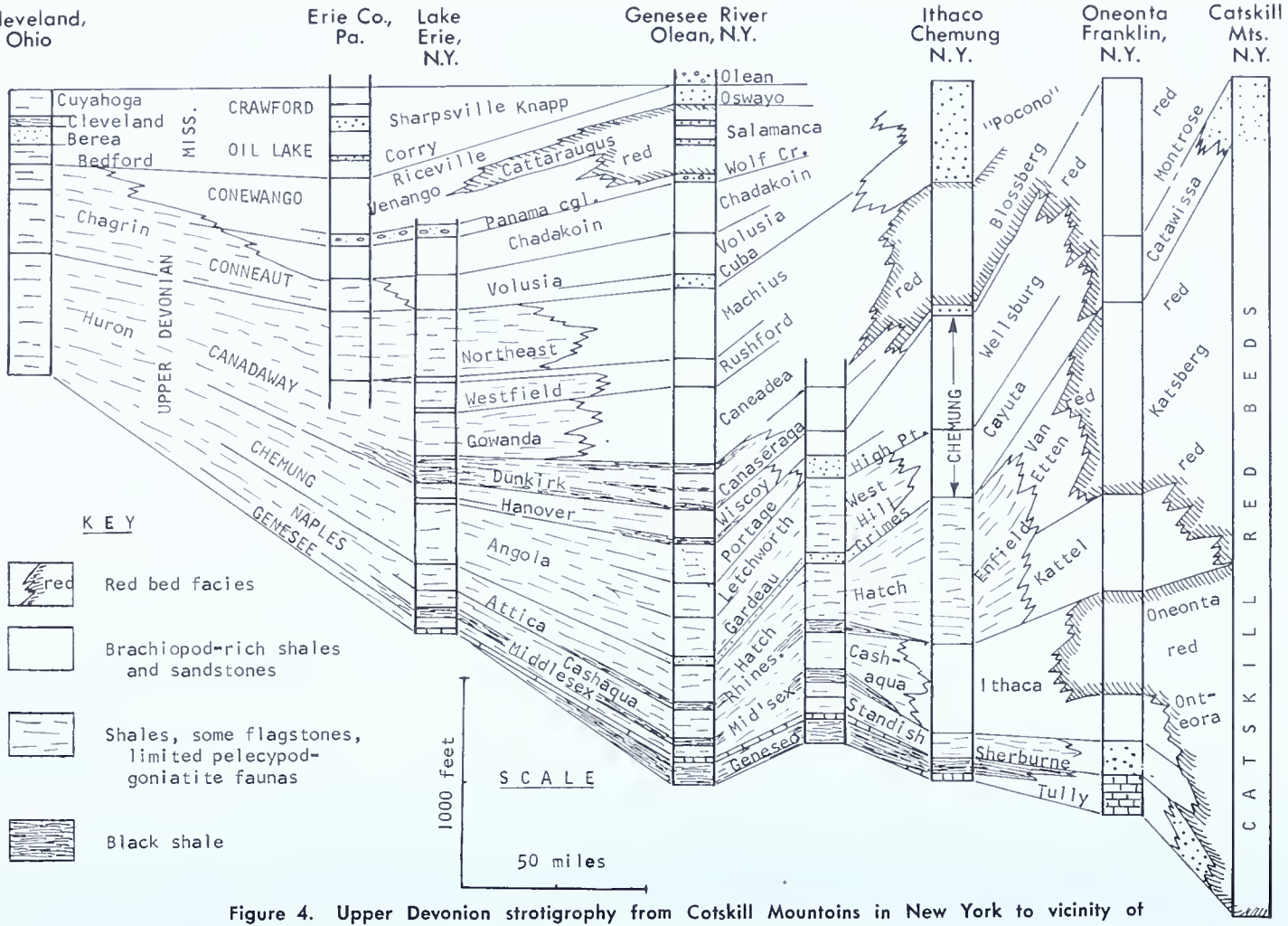


Figure 4. Upper Devonion strotigrophy from Cotskill Mountoins in New York to vicinity of Clevelond, Ohio. From Chadwick (1933, 1935, 1936) ond others.

Chemung sediments of that region. As in the vicinity of Ithaca and Chemung, the Catskill Red Beds above the Chemung are believed to be wholly younger than the rocks of the type Catskill Formation in the Catskill Mountains in eastern New York, but are thought to merit inclusion under the same name since they are comparable in facies, and especially since they constitute with the type Catskill rocks a body that was, and in a degree is physically continuous. Above the Chemung, the general absence in the Catskill Red Beds of remains of shelly organisms is a function of freshening of waters in which the sedimentation occurred. The red ferric oxide which is the source of the vivid color is an indication not only of conditions favorable for oxidation, but also of the subtropical to tropical warmth that in the generally humid climate favored stability of anhydrous hematite rather than of hydrated limonite. In contrast, the sparsity of shelly fossils in the finely micaceous shales of the Brallier Formation which underlie the Chemung at the Curve, plausibly reflects not lowering of salinity but instead deposition in somewhat deepened, offshore marine waters where lessened bottom oxygen, and perhaps hindering of algal growth occasioned by limited penetration of light, were unfavorable for the brachiopod-rich biotas represented in the Chemung accumulations.

The Catskill sediments at Stop No. 11 from 34,146 feet to 38,180 feet of the Horse Shoe Curve traverse, will be crossed as follows.

Catskill Red Beds	*Feet* *Bed*	*Total*
(Continued, below estimated 125 feet in concealed interval from 33,845 to 34,146 feet of traverse)		
Red, somewhat silty mudrock, breaking to hackly fragments. At top are 2 feet of medium-bedded, bright-green, fine-grained sandstone, overlain by 3 feet of greenish-gray shale. At 19 feet below top are 2 feet of greenish-gray shale and sandstone, and below this the red mudrock contains a number of interlayered, 1-inch greenish-gray bands. At 40 to 50 feet below top there are thick-bedded, strongly cross-bedded, fine-grained red sandstones, the base locally channel-cut into the next lower mudrock. There also are irregularities in layering within the mudrock portions due to small-scale cut-and-fill. At 81 to 88 feet below top are 7 feet of cross-bedded, greenish-gray sandstones, underlain by 2 feet of greenish-gray sandstone and shale, and then by 6 feet of red sandstone. Much red sandstone is interbedded in the lower 25 feet. Dip 13° NW. To 34,830 traverse.	155	2035
Thin-bedded, greenish-gray silty shale, with 5 to 10 feet of greenish-gray sandstone at middle. To 35,102 feet traverse.	43	2078
Thick-bedded red sandstone, with a few 1- to 3-inch interlayers of red siltstone or silty shale. Dip 12° NW. To 35,152 feet traverse.	32	2110

Concealed. To 35,895 feet traverse.	190	2300
(Signal Tower: traverse location 35,180 feet. Also culvert at 35,510 feet traverse, watering spouts at 35,975 feet traverse.)		
Red sandstone and interbedded red shale or mudrock, forming cuts in area from 36,120 feet to base. To 36,418 feet traverse.	135	2435
Concealed. To 36,970 feet traverse.	110	2545
Partly concealed, with much red shaly mudrock and siltstone in bank. To 36,990 feet traverse.	28	2573
Thin-bedded, greenish-gray silty sandstone, mostly concealed. To 37,070 feet traverse.	11	2584
Red silty mudrock. To 37,205 feet traverse.	22	2606
Medium- to thick-bedded, much cross-bedded red sandstone, partly concealed. There are several thin interbeds of red mudrock, and one such bed is 10 feet thick. To 37,470 feet traverse.	67	2673
Mostly concealed, with red shaly soil. To 37,600 feet traverse.	32	2705
Mostly concealed, but in general consisting of red mudrock containing some ½- to 1-foot interlayers of fine-grained red sandstone. At 26 to 29 feet below top there are 3 feet of greenish-gray sandstone. Some loose slabs of the red sandstone bear ripple marks, generally of symmetrical or oscillation type. To 37,730 feet traverse.	35	2740
Red mudrock and some thin-bedded red shale, with several 1-foot interlayers of red sandstone, and with 23 feet of nearly continuous red sandstone at 26 to 49 feet below top. Dips 14° NW., 20° NW. To 38,020 feet traverse.	90	2830
Thin-bedded red shale varying to hackly, red mudrock, with a few 2- to 6-inch interlayers of red sandstone. To 38,180 feet traverse.	55	2885
Thickness of Catskill beds exposed at Stop No. 11	1005	
Concealed, to 38,860 feet traverse, in area between rocks of Stops Nos. 11 and 12.	270	3155
(Milepost 240: traverse location 38,835 feet, about in line with dam of lowest of the three reservoirs.)		

STOP NO. 12

MARINE TONGUE AND LOWEST PARTS OF CATSKILL RED BEDS

Greenish-gray shales, 250 to 275 feet above base of the Catskill Red Beds, contain a marine Chemung fauna symptomatic of the westward

interfingering of the red Catskill sediments into marine, brachiopod-rich deposits of the Chemung facies. The fossiliferous shales and the underlying, basal beds of the Catskill Formation, are exposed as follows.

Catskill Red Beds (Continued)	Feet Bed	Feet Total
Marine tongue.—Thin-bedded, greenish-gray shale. Some pelecypods in upper part. At 4 feet above base, a 2-inch layer of conglomeratic sandstone contains crinoid plates, *Schuchertella chemungensis, Camarotoechia* sp., *Tylothyris mesacostalis.* This may be the horizon or about the horizon at which Willard (1933) in addition reported *Schizophoria striatula, Spirifer disjunctus, Sphenotus contractus.*	25	3180
Red shale and mudrock, wth some interlayers of red sandstone in upper part that range to 2 feet in thickness, with one at 39,065 feet traverse that is 3 feet thick. Some interbedded greenish-gray shale and sandstone occurs at 38,990 to 39,005, 39,035 to 39,060, and at 39,120 feet traverse. To 39,325 feet traverse.	180	3360
Medium- to thick-bedded, strongly cross-bedded, greenish-gray sandstone. To 39,365 feet traverse.	17	3377
Red shale and mudrock, with interlayers of red sandstone ranging to ½-foot in thickness. Some interbeds of greenish-gray shale occur in basal 10 feet. To 39,495 feet traverse.	53	3430
Thickness of Catskill Red Beds at and below the marine tongue	275	
Total thickness, as estimated, of Catskill Red Beds	1675	
Chemung Shale		
Thin-bedded, greenish-gray shale, with 6 feet of greenish-gray sandstone at middle and some thin interlayers of sandstone in lower half. Strike and dip N. 19° E., 26° NW. In upper part: *Camarotoechia* sp., *Cyrtospirifer chemungensis.* To 39,588 feet traverse.	40	3470
Thickness, exposed beds at top of Chemung Shale	40	
Concealed, to 40,410 feet traverse, in area between exposures of Stops Nos. 12 and 13.	360	3830
(Marker 2/1: traverse location 40,400 feet.)		

STOP NO. 13

UPPER PART OF CHEMUNG SHALE

Beneath the Catskill Red Beds in the area of the Horse Shoe Curve there are about 4200 feet of Upper Devonian, generally greenish-gray shales and sandstones, underlain by 375 feet of mostly fissile, gray and

some black shales. The strata of the upper 2,600 to 2,700 feet preserve fossil brachiopods at many horizons, and contain sandstone interbeds that decrease in number in the lower part; these rocks constitute the Chemung Shale or Formation and appear to be approximate age equivalents of the Chemung beds of the Ithaca Chemung region in New York. (Compare Figure 4.) Below them, without any well-defined lithologic boundary, are 1,500 feet of greenish-gray shales that tend to be somewhat micaceous and silty but contain few interlayers of sandstone and are only sparsely fossiliferous; these are distinguished as Brallier Shale. Included at the base of the Brallier is a body of very fine-grained sandstone that is 20 feet or somewhat more in thickness and is resistant enough to form a line of low foothills along the northwesterly margin of a low-land belt that follows the outcrop of Middle Devonian Hamilton shales. The sandstone appears to be the thinned, westerly extension of sandstones that are 100 feet or more in thickness at the base of the Brallier at Huntingdon, Pennsylvania, 25 miles east of the Horse Shoe Curve, where they crest Standing Creek Ridge and have been termed Standing Creek Sandstone Member (F. M. Swartz, 1955.) Beneath the sandstone are 300 feet of thin-bedded to fissile, gray argillaceous beds of the Harrell Shale, that in the upper part become greenish gray and somewhat silty before they give place to the Standing Creek sandstones. The Harrell Shale is underlain in turn by about 75 feet of Burket Black Shale, similar in facies to the Geneseo Black Shale of New York and roughly comparable in geologic age. In the vicinity of Schellsburg, 32 miles to the southwest, and on the outskirts of Milesburg near Bellefonte, 45 miles to the northeast, as well as in deep wells 10 miles and more to the west and northwest, 5 or 10 to 25 feet and more of Tully Limestone occur beneath the Burket, but no exposures of the Tully beds have been observed in the nearer vicinity of the Curve. The Burket and Tully as well as the Harrell strata generally have been considered to belong in the basal-most Upper Devonian by previous workers in the region, but the Burket and Tully are included in the uppermost part of the Middle Devonian Erian Series in the Chart for Correlation of Devonian Formations of North America, prepared by Cooper and others (1942).

Exposures along the railroad right-of-way from 39,495 to 45,315 feet of the Horse Shoe Curve traverse, extend across virtually the full thickness of the Chemung Shale, although Butts (1945) placed the lower boundary about 220 feet lower to include 20 feet of shale based by a 2-inch, fossiliferous layer of sandstone. Beyond 45,315 feet, the traverse diverges from the railroad tracks, and along Burgoon Run Road and near Endress School leads to exposures of parts of the Brallier, Harrell and Burket Formations.

In the half-mile thickness of the Chemung Formation, the brachiopod-rich faunas are characterized especially by the wide-winged, multicostate species, *Cyrtospirifer chemungensis* (Conrad, 1842),* which is illustrated in Figure 5 together with several other characteristic Chemung fossils that also are found in the section at the Horse Shoe Curve. Presumably in part because of comparative rapidity of accumulation of the Chemung sediments and the sufficient stability of environment so that brachiopod-rich layers are recurrent at many levels, but perhaps also in part due to a no-more-than-moderate pace in evolution of the shelly animals of the ancient Chemung seas, changes in the fossil Chemung faunas do not as now understood mark zonal intervals that are as closely spaced as those found in Lower Devonian and many older strata of the region. Nevertheless, significant faunal differences are apparent at the successive railroad cuts in which parts of the Chemung Formation are exposed for examination, and future work is needed here as elsewhere to show more clearly the occurrences and distributions of species and to give further consideration to possible ecologic interrelationships. Observed features of the rock as well as fossil succession can be summarized as follows, and are presented in further detail in description of portions of the Chemung section as exposed at the respective stops.

Uppermost beds of Chemung Formation, exposed next beneath Catskill Red Beds at 38,495 to 39,588 feet traverse.—Greenish-gray shale and some interbeds of fine-grained sandstone. Thickness 40 feet. *Cyrtospirifer chemungensis* (Conrad) is common.

Concealed, to 40,410 feet traverse. Thickness 360 feet, total below top of Chemung 400 feet.

First Chemung cut, to 41,060 feet traverse.—Greenish-gray and some purplish- or chocolate-colored shales, with interbeds of sandstone. A 2-foot bed of conglomerate, with ½-inch pebbles of quartz, flattened in the manner caused by beach scour, occurs in upper part. Ripple marks were observed at 65 feet below top and 35 feet above base. Small-scale scour-and-fill structures mark bottoms of some of sandstone layers in lower half. "Storm-rollers", presumably originated by penecontemporaneous slumping, occur in sandy beds at 50 feet above base. Thickness 270 feet, total 670 feet. *Cyrtospirifer chemungensis* (Conrad) is common at numerous levels. Coarse-ribbed *Atrypa hystrix* Hall occurs in lower part.

Concealed, to 41,885 feet traverse. Thickness 330 feet, total 1,000 feet.

* Following the opinion of James Hall (1867), the cyrtospiriferid common in the Chemung-age deposits of the Appalachian region has been identified for many years with *Spirifer disjunctus* Sowerby (1840) of the Upper Devonian of Devonshire in Great Britain. The markedly more alate outline and lesser convexity of the species, and the lower height of the ventral area and lesser length of the dental plates, has been recognized by H. Greiner (1957), and also by D. Bye (1949) in an unpublished Master's Thesis at the Pennsylvania State University. Resurrection of Conrad's name as proposed by Greiner is appropriate.

Second Chemung cut, to 42,360 feet traverse.—Greenish-gray shale, with interbeds of gray sandstone more common in upper than in lower half. There are "storm-rollers" at 48 to 54 feet below top, small-scale cut-and-fill structures at several levels at 112 to 122 feet below top. Thickness 260 feet, total 1,260 feet. *Cyrtospirifer chemungensis* (Conrad) is less abundant than in first cut. *Platyrachella mesastrialis* (Hall) occurs near top, in sandstone considered by Butts (1945) to be representative of the Saxton conglomerate.

Concealed, to 43,029 feet traverse. Thickness 335 feet, total 1595 feet.

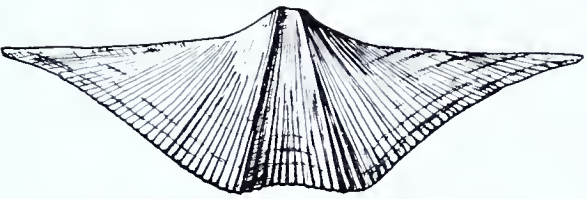
Third Chemung cut, to 43,449 feet traverse.—Greenish-gray shale, with some interbedded sandstone. There are curved structures of general "storm-roller" type at 145 feet below top, some small-scale cross-bedding in several sandstones in lower 20 feet. Thickness 225 feet, total 1,820 feet. *Douvillina cayuta* (Hall), *Tylothyris mesacostalis* (Hall) and *Ambocoelia umbonata* (Conrad) are common at many levels. *Atrypa* sp. with ribbing intermediate between that of *A. spinosa* Hall and *A. hystrix* Hall, occurs in upper beds. *Cyrtospirifer chemungensis* was not observed.

Concealed, to 44,650 feet traverse. Thickness 550 feet, total 2,370 feet.

Fourth Chemung cut, to 45,315 feet traverse.—Greenish-gray shale, with interbeds of gray sandstone that are thinner and less numerous than those in the other cuts. Thickness 295 feet, total 2,665 feet. *Cariniferella tioga* (Hall) and *Ambocoelia umbonata* (Conrad) are common to abundant at numerous levels, and *Douvillina cayuta* (Hall), *Schizophoria striatula* (Schlotheim), *Atrypa reticularis* (Linnaeus) and *A. spinosa* Hall also are found. *Cyrtospirifer chemungensis* (Conrad) was not observed.

Concealed to southeast. Butts (1945) drew the lower boundary of the Chemung Formation about 220 feet thickness below the lowest rocks exposed at the fourth Chemung cut, as judged from his discussion, to include 20 feet of shale based by a 2-inch layer of sandstone in which he reported *Leiorhynchus mesacostale* Hall and *Productella speciosa* Hall. Estimated thickness of Chemung including these beds would be 2,885 feet.

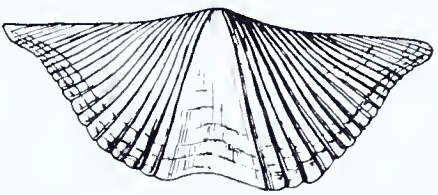
Among lithologic features of the Chemung deposits, the grayish-purple or chocolate-like color of parts of the upper beds at the first Chemung cut is a common feature of the marine sedimentary phase that lies first to the west of the fresh-water, or at least relatively fresh-water, red accumulations of the Catskill facies. Near-shore conditions further are evidenced at both the first and second cuts by small-scale scour-and-fill structures that suggest the work of waves and shallow-water currents. Although some of the thicker bodies of sandstone, especially where marked by well-defined cross-bedding, may be parts of beach or near-beach deposits, it is likely that most of the layers are formed of sands that were carried some distance off-shore. In the general area of the Allegheny Front, beach accumulations appear to be limited in development or at least in preservation at the lateral interface between the Chemung and its more easterly equivalents in the Catskill facies, perhaps because the sedimentary input from the east was large and clayey in relation to effectiveness of the waves moving in across the shallow reaches of the Chemung waters. Subaqueous slump-



Cyrtospirifer chemungensis (Conrad)
ventral exterior

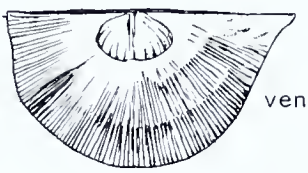
Tylothyris mesacostalis (Hall)
ventral exterior

ventral interior



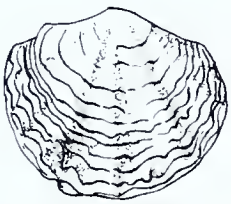
Platyrachella mesastrialis (Hall)
dorsal exterior

ventral exterior
Cariniferella tioga (Hall)



ventral interior

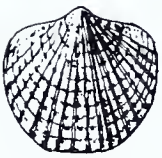
Douvillina cayuta (Hall)



Atrypa hystrix Hall
ventral exterior

ventral exterior

Schuchertella chemungensis (Conrad)
ventral exterior



Atrypa spinosa Hall
ventral exterior

Figure 5. Sketches illustrative of some common chemung fossils.

ing, favored locally by active buildup of gentle but nevertheless unstable slopes, appears to have given origin to the peculiar enrollments of "storm-roller" beds, comparable to those noted by Chadwick (1931) in the Upper Devonian of eastern New York. The lack of purplish beds at the second, third and fourth cuts, and lesser development of cut-and-fill and of "storm-rollers" at the third and fourth cuts, as well as the reduction in proportion of interlayers of sandstone, all suggest deposition in areas somewhat more offshore than the locale represented by the shales and sandstones of the first cut.

The fossil record for the Chemung Shale at the Horse Shoe Curve no doubt could be much enlarged if collecting were undertaken with greater intensity than was attempted during measurement of the section for the present account. Nevertheless, even with present information there are several features that appear noteworthy, at least on a preliminary basis and subject to further study.

At all four of the Chemung cuts, the recurrent brachiopod-rich layers give evidence that the waters of accumulation generally were marine in salinity, and well oxygenated and well supplied with food, as well as that the temperatures were favorable for brachiopod growth and presumably were warm. Where present, especially in the third and fourth cuts, the valves usually tend to be separated and to be arranged with the convex side upward. So far as observed, there is little evidence of the wear and fragmentation that would be expected at positions of active beaches and near-beach shallows. The flat pebbles of the 2-foot conglomerate in the upper part of the beds at the first cut plausibly were shaped by beach wear, but may have been transported in their present form to the location of deposition. Abundance of shells in the more fossiliferous layers may well have involved some degree of mechanical concentration, but in view of the freedom from abrasion give evidence of the general profusion of growth of shell-bearing organisms in the general area of the places of burial.

The following stratigraphic distributions of the observed species deserve consideration, subject to further collecting and study:

1. *Cyrtospirifer chemungensis* (Conrad) is common to abundant at many levels in the 40 feet of shale exposed at the top of the Chemung at the Horse Shoe Curve, and in beds of the first Chemung cut at 400 to 670 feet below the top. Poorly preserved examples were obtained in the second cut at 1,000 to 1,260 feet below the top. No specimens were observed in the third and fourth cuts, respectively at 1,595 to 1,820 and 2,370 to 2,665 feet below the top of the Chemung, although some occurrences would be expected since the species has been found loose by the writer in the *Cariniferella tioga* zone of the lower Chemung along highway No. 164 west of East Freedom, 9½ miles southwest of the Horse Shoe Curve, and occurs in place in the same zone at Ellerslie on the Pennsylvania-Maryland line as reported by

C. K. Swartz (1913c). Along highway No. 30 on the easterly flank of the Schellsburg anticline, 32 miles southwest of the Curve, the writer has collected *Cyrtospirifer chemungensis* in abundance in beds close above the top of the *Cariniferella tioga* zone, at levels that should fall between the horizons represented by the third and fourth Chemung cuts at the Horse Shoe Curve.

2. *Cariniferella tioga* (Hall) is common to abundant in beds at the fourth cut at 2,370 to 2,665 feet below the top of the Chemung Formation, but was not observed at higher positions. It thus marks a zone in the lower Chemung beds at the Horse Shoe Curve as it does near Ellerslie on the Maryland-Pennsylvania line (C. K. Swartz, 1913b,c), and likewise near East Freedom and Schellsburg in Pennsylvania, and provides a valuable tool in correlations along this part of the foot of the Allegheny Front. Although *Cyrtospirifer chemungensis* may be found in the future in the *Cariniferella tioga* zone at the Horse Shoe Curve as at East Freedom and Ellerslie, it is at the most inconspicuous in the exposed beds of the horizon.

3. Coarse-ribbed and spinose *Atrypa hystrix* Hall occurs at the first Chemung cut at the Horse Shoe Curve, where it was observed at about 600 feet below the top of the Chemung Formation, and the more finely ribbed *A. spinosa* Hall is fairly common in the fourth cut at 2,370 to 2,665 feet below the top. Specimens with intermediate strength of ribbing, listed in the section description as *"Atrypa spinosa* var. near *A. hystrix"*, were found in the third cut at about 1,650 feet below top of the Chemung.

4. *Douvillina cayuta* (Hall) is a strikingly characterized Chemung strophomenid that is common to abundant in some beds in the third and fourth cuts at 1,595 to 1,820 and 2,370 to 2,665 feet below the top of the Chemung. Examples of *Productella*, generally comparable to *Productella lachrymosa* (Conrad) and *P. speciosa* Hall, were obtained at similar levels. *Ambocoelia umbonata* (Conrad) is abundant at numerous horizons in the third and fourth cuts, and was found at the second cut in beds as high as 1,170 feet below the top of the Chemung. In description of the first Chemung cut, "other fossils" were noted at several levels in association with *Cyrtospirifer chemungensis,* but identification and listing were not undertaken.

Some of the observed differences in the faunas at successive levels in the Chemung Formation at the Horse Shoe Curve appear to reflect the progress of evolution, whereas others plausibly are related in varying degree to modifications in environment. Thus the medium-ribbed *"Atrypa spinosa* var. near *A. hystrix"* found at the third cut, presumably is representative of a connecting evolutionary link between the more narrowly ribbed *A. spinosa* Hall of the lower Chemung of the fourth cut, and the more widely-ribbed *A. hystrix* found in the first cut, even though the ranges of the two species are reported to overlap elsewhere as at Ellerslie. On the other hand, the diversity that marks the brachiopod assemblages at the third and fourth cuts, including the occurrence of prone-lying strophomenids and spine-anchored productellids, may well reflect somewhat offshore waters, perhaps with less variation in salinity and less rapid input of sediment, than do the faunas of the first and perhaps the second cuts. In the case of *Cariniferella tioga*, a somewhat off-

shore location was indicated 50 years ago in the work of C. K. Swartz (1913b,c,d), who found that the species is common in the "lower sandstone and shale member of the Chemung" near Ellerslie on the Maryland-Pennsylvania line, whereas it is wanting so far as observed in beds considered chronologically equivalent farther to the east, although other brachiopods including *Cyrtospirifer chemungensis,* persist for perhaps 15 miles before the strata develop increasing proportions of red strata.*

In both its eastward persistence in the lower Chemung in Maryland, and its abundance in the upper Chemung at the Horse Shoe Curve, *Cyrtospirifer chemungensis* gives evidence that it was able to flourish during its life period well towards the eastward margin of the marine portions of the Appalachian area of sedimentation, whereas its sparsity at the fourth and perhaps the third cuts at the Curve, where brachiopod-rich layers are weathered in a fashion to aid ease of observation, suggests that it tended to give place offshore toward the west to other species even where brachiopod assemblages still were profuse. Somewhat as at the Curve, Greiner (1957) has noted that in New York *C. chemungensis* and other members of its genus are sparse or wanting where dalmanellids such as *Cariniferella tioga* are abundant.

In the upper Chemung beds in the first Chemung cut at the Curve, where *Cyrtospirifer chemungensis* was observed at numerous levels, the presence of accompanying fossils was mentioned in the course of description of the section, but listing of species was not undertaken. At Shellsburg to the southwest of the Curve, as well as northwest of Bellefonte to the northeast, productellids of the type of *Productella lachrymosa* and *P. speciosa,* the strophomenid *Schuchertella chemungensis,* and the atrypid *Atrypa hystrix,* are among the common associates of *Cyrtospirifer chemungensis* in at least parts of the middle and upper Chemung. Further study is needed at the Curve to give information about the occurrence of these and other members of the Chemung fauna, and perhaps to discover whether there is any increase in pelecypods and gastropods in

* In "Columnar Sections of the Jennings Formation of Maryland" (C. K. Swartz, 1913d), *Cariniferella ("Dalmanella") tioga,* cited as fossil No. 43, is shown at Ellerslie in the lower member of the Chemung, together with occurrences of *Cyrtospirifer chemungensis ("Spirifer disjunctus"),* No. 66, and other fossils, but is wanting in the easterly extensions of the same beds at Williams Road and National Road on Polish Mountain and at Town Creek, where there are occurrences of *C. chemungensis* together with some other brachiopods and a number of pelecypods and gastropods. Near Pawpaw, Green Ridge and Little Orleans in Maryland, and at Mann and in Thompson Township in Fulton County, Pennsylvania, red beds are dominant at the presumed correlative horizons, and there are few citations of fossils although some are reported in interlayers between the red beds at National Road near Millstone in Maryland.

the more shoreward parts of the deposits. At Runville, 45 miles northeast of the Curve and 5 miles northwest of Bellefonte, *C. chemungensis* occurs at several levels in the red beds of the lowest 100 feet of the Catskill Formation, indicating on the one hand that at times there was sufficiently rapid input of sediment as compared to reduction by organic matter, so that the westerly margin of the red accumulations extended for short distances into the area occupied by marine organisms; and likewise showing on the other hand that *C. chemungensis* was capable of ranging essentially to the eastward margin of the habitat that can be classed as marine on the basis of its shelly inhabitants. A number of the specimens in the red beds at Runville retain conjoined valves, suggesting both rapid burial as well as that the shoreward margin of the marine-water facies, where it joined the area of red sedimentation, was not marked by an active beach, again perhaps because input of sediments was rapid, in this instance in terms of the effective work of waves entering from the shallow waters toward the west. Further collecting in central Pennsylvania as elsewhere, giving attention to the association of species in the Chemung as in other faunas, the condition and disposition of the shells, and the geographic and stratigraphic distributions, should continue to yield pertinent information and provide the basis for improved inferences concerning the life conditions and environments of the time.

Turning from the general relations of the Chemung faunas and sediments to details of the Chemung succession at the Horse Shoe Curve, the rocks and fossils at Stop No. 13 in the first Chemung cut can be described as follows:

Chemung Shale (Continued)	Feet Bed	Feet Total
Thin-bedded greenish-gray shale with some thin interlayers of gray sandstone; sandstone interlayers are few at 75 to 100 feet below top and in basal 3 feet. Shales at 30 to 60 feet below top are in part purplish gray or chocolate colored. Ripple marks occur at 40,590 feet traverse. *Cyrtospirifer chemungensis* and other fossils are common in layers at 40,420, 40,460, 40,500, and 40,590 feet traverse. To 40,716 feet traverse.	108	3938
(Signal Tower: traverse location 40,640 feet.)		
Medium-bedded, flat-pebble conglomeratic sandstone and conglomerate. Pebbles mostly are milky quartz and are about ½ inch in diameter, with a very few examples that reach 1½ to 2 inches. The pebbles are flattened in the manner suggestive of beach-scour rather than river-rolling.	2	3940
Medium-bedded, gray sandstone and some interbedded greenish-gray shale. To 40,746 feet traverse.	30	3970

Thin-bedded, greenish-weathered and some purplish-gray or chocolate-colored shale, in part with much interbedded gray sandstone in which some interlayers reach thicknesses of ½ to 1 foot, and at places on basal surfaces show effects of scour-and-fill. The scour-and-fill structures are small in scale as compared to those common in the Pocono, Pottsville and Allegheny Formations, and may reflect wave-trenching and erosion and deposition by currents in shallow waters, as well perhaps as some rill-cuts on tidal flats, as compared to the channel cuts and deposits of distributary streams. At 40,945 feet traverse are subconcentric structures of "storm-roller" type, and symmetrical ripple marks occur at 40,975 feet. At 40,880 feet traverse, 57 feet below top of this unit: *Cyrtospirifer chemungensis* (c), *Atrypa hystrix* (c). Strikes and dips N. 24° E., 30° NW. To 41,060 feet traverse.	130	4100
Thickness of beds exposed in first cut in Chemung Shale	270	
(Railroad Tower House: traverse location 41,050 feet.)		
Concealed, in area between Chemung cuts 1 and 2. To 41,855 feet traverse.	330	4430

STOP NO. 14

SECOND CUT IN CHEMUNG SHALE

Four 10-foot interbodies of fairly well cemented sandstone occur in the upper half of the beds at the second cut in the Chemung Shale, and there is a lesser thickness of thinner interbeds in the lower half. In attempting to judge the proportion of sandstones in the Chemung Formation at the Horse Shoe Curve section, it should be recognized that the railroad cuts expose sequences only in knolls or low ridges that presumably have at least some tendency to represent the more resistant portions of the succession, so that sandstone interbeds may be somewhat more numerous in the railroad cuts than in the intervals concealed across the intervening hollows.

Fine specimens of *Platyrachella mesastrialis* (Hall) have been obtained at 10 feet below top of the rocks of the second cut. The horizon can be recognized by the small cavities left where shells have been removed by modern weathering. "Storm rollers" are prominent near the middle of the cut.

The rocks of the second cut are as follows:

Chemung Shale (Continued)	Feet Bed	Feet Total
Thin-bedded, greenish-gray shale and some sandstone.	5	4435
Medium-bedded, gray sandstone and a little interbedded shale. *Platyrachella mesastrialis* (a) 3½ feet above base. These appear		

to be the beds considered by Butts (1945) to be representative of the Saxton Conglomerate as developed father to the east in the Huntingdon quadrangle. To 41,867 feet traverse.	9	4444
Thin-bedded greenish-gray shale, with several thin interlayers of gray sandstone. To 41,930 feet traverse.	24	4468
Thick-bedded gray sandstone. To 41,947 feet traverse.	10	4478
Thin-bedded, greenish-gray shale, with curved, sandy layers forming "storm-rollers" in upper 6 feet and 15 feet below top. There are several 2- to 6-inch interlayers of sandstone at 24 to 30 feet below top. To 42,039 feet traverse.	44	4522
Medium-bedded gray sandstone with subordinate, interbedded shale near top. To 42,060 feet traverse.	11	4533
Thin-bedded greenish-gray shale and some interbedded sandstone. To 42,078 feet traverse.	9	4542
Medium-bedded gray sandstone and some interbedded greenish-gray shale. Sandstone bed 6 to 7½ feet below top is calcareous, and contains curved layers of "storm-roller" type. Symmetrical ripple marks occur in upper 2 feet, at 42,081 feet traverse. Basal surfaces of sandstone layers are at some places marked by small-scale cut-and-fill. At 6 inches below top: imperfectly preserved spiriferids, possibly *Cyrtospirifer chemungensis*. At 2 feet below top: *Camarotoechia* sp. Strike and dip: N. 21° E., 28° NW. To 42,095 feet traverse.	10	4552
Thin-bedded greenish-gray shale, with thin interlayers of sandstone at 20 to 32 feet below top.	48	4600
Thin-bedded gray sandstone and some interbedded greenish-gray shale, forming a fairly prominent rib in the wall of the cut. *Ambocoelia umbonata* (a) at base.	3	4603
Thin-bedded, greenish-gray shale with a few thin interlayers of gray sandstone, the thicker interlayers ½-foot to 1½ feet in thickness at 35, 39 and 44 feet above base. To 42,360 feet traverse.	87	4690
Thickness of beds exposed in second cut in Chemung Shale	260	
Concealed, in area between second and third cuts in Chemung Shale. To 43,029 feet traverse.	335	5025

(Note views toward southeast of mountains neighboring Canoe Creek Valley.)

STOP NO. 15

THIRD CUT IN CHEMUNG SHALE

Chemung fossils are abundant in various beds at the third cut in the Chemung Shale, and the conditions of weathering tend to permit break-

age of surfaces favorable for their observation. *Douvillina cayuta* (Hall), *Tylothyris mesacostalis* (Hall) and *Ambocoelia umbonata* (Conrad) all occur in lower and middle as well as upper beds. There are examples of *Atrypa* at both lower and upper levels, *Productella* sp. is common in upper beds, and unidentified bryozoans are abundant at one horizon near the middle of the succession. *Cyrtospirifer chemungensis* (Conrad) which is conspicuous in fossiliferous beds at the first Chemung cut, was not observed here in the course of the somewhat limited observations undertaken for the present report, and appears to be sparse although it well may be found in the course of future collecting.

Chemung Shale (Continued)	Feet Bed	Feet Total
Thin-bedded, greenish-gray shale with a few thin interlayers of sandstone. Upper 45 feet much concealed.	55	5080
Thin-bedded, laminated and in part cross-laminated gray sandstone, with interbedded greenish-gray shale predominant 10 to 15 feet above base and forming about half of total in remainder of rock. At several levels in upper 5 feet: *Douvillina cayuta* (c), *Productella* sp. (c), *Atrypa spinosa* var. near *A. hystrix*, with intermediate strength of ribbing (c), *Tylothyris mesacostalis* (r), *Ambocoelia umbonata* (a). Dip 30° NW.	22	5102
Thin-bedded, greenish-gray shale with a few 1- to 4-inch interlayers of sandstone.	21	5123
Thin-bedded, greenish-gray shale, with 3- to 6-inch interlayers of sandstone that form a third to a half of total of the rock. At base are several small, faulted flexures. There is a 1-foot interbed of sandstone at 25 feet above base, and at 15 feet above base are curved presumed slump structures. At top, in basal portion of a 1½- to 2-foot bed of sandstone: bryozoans (a); *Douvillina cayuta* (c), *Tylothyris mesacostalis* (r), *Ambocoelia umbonata* (c).	62	5185
Thin-bedded, greenish-gray shale with a few 1- to 2-inch interlayers of sandstone.	44	5229
Thin-bedded, greenish-gray shale, containing several 1- to 1½-foot interlayers of sandstone, some of which are marked by small-scale cross-lamination. Strike and dip: N. 26° E., 33° NW. At 6 feet below top: *Douvillina cayuta* (c), *Atrypa reticularis* (r), *Tylothyris mesacostalis* (r), *Ambocoelia umbonata* (c). To 43,449 feet traverse.	21	5250
Thickness of beds exposed in third cut in Chemung Shale	225	
Concealed in area from third to fourth cuts in Chemung Shale. To 44,650 feet traverse.	550	5800

(Milepost 239: traverse location 44,435 feet.)

STOP NO. 16

LOWER PART OF CHEMUNG SHALE

The fourth railroad cut in the Chemung Shale exposes the *Cariniferella tioga* beds that lie close to the base of the formation. Sandstone interlayers are thin and less conspicuous than in the other cuts, although they still are fairly numerous.

Chemung Shale (Continued)	Feet Bed	Feet Total
Thin-bedded gray sandstone, in layers 1 to 6 inches thick, and interbedded greenish-gray shale that forms about one-third of total.	37	5837
Thin-bedded, greenish-gray shale with a few 1- to 3-inch interlayers of sandstone at 9 to 10 feet below top that contain *Schizophoria striatula* (r), *Productella* sp. (c), *Atrypa reticularis* (r).	56	5893
Thin-bedded, greenish-gray shale, with some thin interlayers of sandstone in upper 47 feet that commonly are 1 to 4 inches thick, and with several 6- to 10-inch interlayers in interval from 47 to 90 feet below top. At 3 feet below top: *Cariniferella tioga* (c), *Ambocoelia umbonata* (c). At 12 feet below top: *Ambocoelia umbonata* (a). At 17 feet below top: *Cariniferella tioga* (c), *Atrypa spinosa* (r). At 37 feet below top, on underside of a 2-inch sandstone of an overhanging ledge: *Douvillina cayuta* (r), *Cariniferella tioga*, fine (c), *Atrypa spinosa* (c).	97	5990
Thin-bedded, greenish-gray shale. In basal 1½ feet there are two 4-inch to 7-inch interlayers of sandstone; a 6-inch interlayer occurs at 14½ feet above base, a 2- to 6-inch interlayer at 49 feet, and there are 1- to 3-inch interlayers at 39 to 49 feet. At 29 to 30 feet above base: *Cariniferella tioga* (c), *Ambocoelia umbonata* (c).	68	6058
Thin-bedded, greenish-gray shale.	20	6078
Thin-bedded, greenish-gray shale with several 1- to 3-inch interlayers of sandstone. At 4 feet above base: *Productella* sp. To 45,315 feet traverse.	17	6095

Thickness of beds exposed in fourth cut in Chemung Shale 295

Thickness of Chemung beds, from 39,495 to 45,315 feet traverse 2665

Concealed, along and near railroad tracks. Butts (1945) reported *Leirhynchus limitare* and *Productella speciosa* in a 2-inch sandstone at the base of 20 feet of shale, apparently at 200 to 220 feet thickness below the base of the rocks of the fourth Chemung cut, and considered that these represent the base of the Chemung Formation. With their inclusion, thickness of the Chemung Shale would be about 2885 feet.

CONTINUATION OF TRAVERSE TO BURGOON RUN ROAD AND TO ENDRESS SCHOOL

Beyond 45,315 feet traverse, the railroad right-of-way curves to the northeast, approaching the line of strike of the bedrock, and exposures are poor. In consequence, the traverse for the section is transferred to Burgoon Run Road, where it is continued toward the southeast to the area of Burket village as marked on the Hollidaysburg topographic sheet, and to Endress School.

At the position where the traverse leaves the railroad, there are fine views toward the southeast where topographic conditions are expressive of many features of the stratigraphic and structural geology. (See Fig. 7.) In the relatively near foreground, about 2,500 feet from the tracks, is the line of low foothills made by the Standing Creek Sandstone Member at the base of the Brallier Formation. Farther away, at about one and one-quarter miles, are somewhat higher knolls formed by Oriskany sandstone and Helderberg and Keyser limestones, dipping generally to the northwest on the flank of the Nittany arch but warped by secondary folding.

Farther to the southeast are ridges made by the lower Silurian Tuscarora Quartzite, that are marked by slides of the white Tuscarora boulders. On the far side of synclinal Canoe Creek valley, nine miles to the southeast, the Tuscarora rises to form Lock Mountain. At four to five miles, the broad entrance to the valley is constricted on the north by the gently sloping anticlinal nose of Brush Mountain, pitching to the southwest, and on the south by the more steeply sloping anticlinal nose of Loop Mountain, pitching towards the northeast. The nearer limb of Loop Mountain is separated on the southwest by Dry Gap from its continuation in Short Mountain, which in one and one-half miles is in turn cut off by McKee Gap beyond which the ridge along the same strike belt is known as Dunning Mountain. On the far side of Short and Dunning Mountains, broad Morrison Cove is cut into Cambro-Ordovician limestones and dolomites brought to the surface along the axial region of the great anticlinal Nittany arch, which is complicated by faults, and by folds such as the doubly-terminated syncline of Canoe Creek valley.

Turning again to the Upper Devonian section, the line of traverse used for the connection from the fourth Chemung cut to exposures of parts of the Brallier, Harrell and Burket beds, leaves the railroad at 43,315 feet traverse and runs about S. 30° E. along the summit of a low topographic spur for 1,000 feet to the Burgoon Run Road. The traverse then extends eastwardly along this road toward Burket village as marked on the Hollidaysburg topographic sheet, although the name does not seem to

be known to present residents of the area. Brallier shales are exposed along the road at about 200 feet east of the point where the Burgoon Run Road is first intersected. The Brallier Formation consists of greenish-gray, somewhat micaceous and silty shales with few of the interlayers of sandstone that are common in the exposed parts of the Chemung Shale, and lacks the numerous fossiliferous layers found in that formation. Butts (personal communication) has regarded *Pteridichnites biseriatus* C. K. Swartz (1913), possibly representative of egg cases of a Devonian shark, as perhaps the most distinctive Brallier fossil, but specimens are few. Goniatites rarely are found in Brallier beds along the Allegheny Front. At 2,000 feet farther along the traverse along the Burgoon Run Road, are small quarry openings in the 20 feet of very fine-grained sandstones of the Standing Creek Member that marks the base of the Brallier Formation and crests a line of hills that are low and not very conspicuous but aid understanding of the areal geology. Thickness of the Brallier Formation is about 1,500 feet. At its base, the dip has steepened to about 50° northwest, from the 3° in the Upper Conoquenessing (?) sandstone near Gallitzin and the 12° to 13° at 34,830 to 35,150 feet traverse in the Catskill Red Beds.

From the base of the Standing Creek Sandstone Member of the Brallier Formation at the small quarry pits, the traverse continues eastwardly along Burgoon Run Road for about 500 feet, then turns to the right or southwest along a cross street and reaches Endress School in about another 1,000 feet. Upper beds of the Burket Black Shale, about 25 feet in thickness, are exposed just to the southwest of the School, and are overlain directly by the gray Harrell Shale, 300 feet, then by loose blocks from the Standing Creek Sandstone Member of the Brallier Formation. The shales of the lower 120 feet of the Harrell are fissile, soft and gray, with some dark-gray to black shale at 4 to 5 and 15 to 16 feet above the base suggesting that these strata elsewhere may become incorporated in the upper portion of the Burket Black Shale. The shales at 81 to 82 and 112 to 115 feet above base of the Harrell are dark gray. In the upper 180 feet, some parts of the Harrell shales become finely silty, and are thin-bedded rather than fissile, the change apparently representing an initial stage in the coarsening of detritus that in time introduced the very fine sands of the Standing Creek Member.

Below the Burket, no further exposures were found in the spreading residential area near Endress School.

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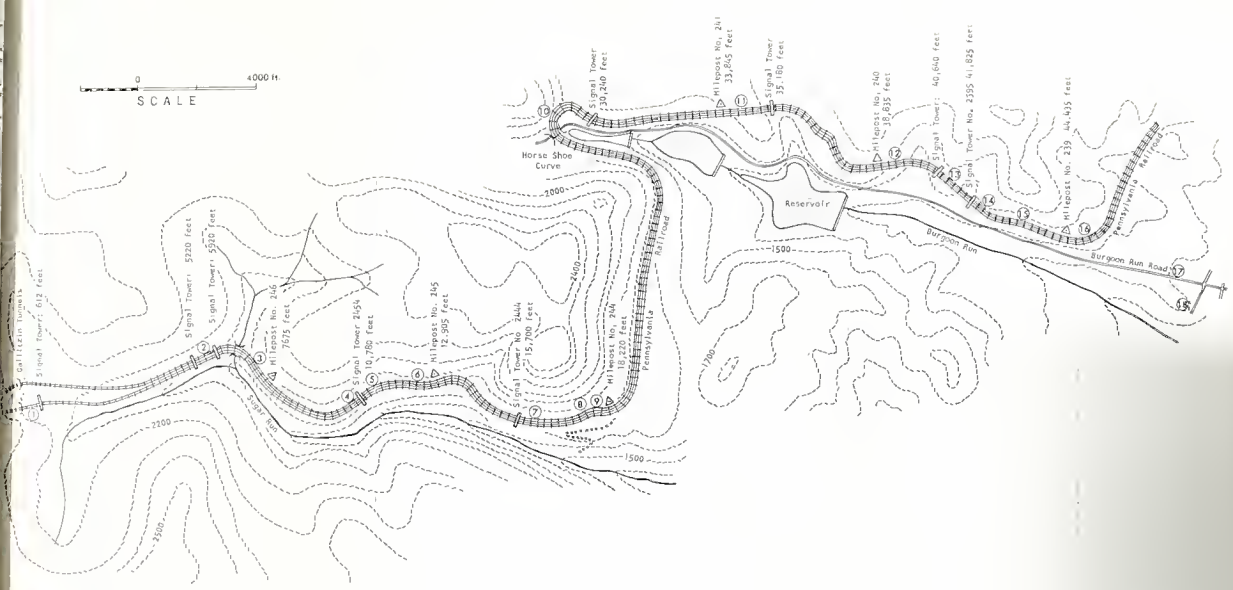

Figure 6. Index map for the Horse Shoe Curve section, showing locations of stops and landmarks.

Figure 7 Topographic index map of parts of central Pennsylvania, showing location of the map, in figure 6, of the area of the Horse Shoe Curve section. The Curve is located on the Allegheny Front, which marks the junction between the Allegheny Plateau Province, underlain with relatively flat-lying Carboniferous and to some areas Devonian strata, to the northwest, and the Appalachian Ridge and Valley Province of strongly folded Paleozoic rocks, to the southeast. The east and one-half mile thickness of Lower Pennsylvanian, Mississippian and Upper Devonian deposits duplicated in the vicinity of the Curve dips gently westward into and beneath the east limbs of the steeply synclinal region underlying between Gallitzin and Johnstown, with Mississippian rocks again brought to the surface along the axis of the anticline at Laurel Hill, while some highest Upper Devonian beds also are exposed locally in Conemaugh Gorge northwest of Johnstown. Southeastward from the Curve Pennsylvania coal-bearing beds occur east of Riddlesburg in the most deeply downfolded part of the Broad Top Basin and the Mississippian Pocono Sandstone crests Tussey Mountain and Sideling Hill in the synclines' limbs. In the intervening area the highest Paleozoic strata have been removed from the axial portion of the strongly elevated, overthrust-faulted and in places excessively folded Nittany Arch, where erosion has cut deeply into Ordovician and Cambrian limestones and dolomites along Fike Gap and Mosiers Caves and Williamsburg and Nittany Valleys. On clear days, there are fine views at several of the described stops of the section at the Curve of Duncansville Loop, Lock and Brush Mountains, oriented to the northwesterly limb of the Nittany Arch by the greatest steeply dipping Early Silurian Tuscarora Quartzite, which provides white boulders that are prominent on many talus slopes over as viewed from distances of 5 to 10 miles. The valley region between the Allegheny Front and Dunning and Brush Mountains, like that between Tyrone and Tussey Mountains, is dissected in Devonian and Silurian shales, sandstone and some limestones, which on either flank dip generally away from the axis of the Nittany Arch